Proposed
Bathymetric Surface Product Specification
S.102

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Proposed Revised
Bathymetric Surface Product Specification
S.102

Forward

This document describes a proposed revised **Bathymetric Surface Product Specification S.102** based on the document S.102 Edition 1.0 July 2008. The document restructures the earlier S.102 specification to align with the concept of **S.10x Auxiliary Information Layer Integration for use with ENC,** and with the **ISO standards 19129** and **19123.** It describes S.102 as an ISO 19131 compliant product specification and shows the inheritance from the ISO and S.100 models. Two separate encodings are described, one in HDF5 and the other using GeoTIFF and XML. A future JPEG 2000 encoding is identified. The following text is proposed wording for the revised product specification.

The format of this document aligns with both the format for a standard as used in ISO and also that for product specification as described in ISO standard 19131:2007 Data Product Specification. Since there is a small difference between these two document formats, this document is a compromise including all of the information required for both but including the preamble required in a standard.

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Introduction

With the advent of electronic navigation, the need for high resolution bathymetric data, or a bathymetric model, has become a requirement for fusion of temporal data such as tidal heights. Furthermore, having this model available allows the ECS or ECDIS to make other intelligent adjustments such as contour intervals.

One key issue is to ensure the depths in the model are verified and certified by the hydrographer. This has been done by including a second discrete point set, called a tracking list, that can be used to generate a correction discrete coverage, which when conflated with the measured bathymetric coverage produces a certifiable navigation surface. This approach is based on the Open Navigation Surface (ONS) Project [1].

This document serves as an S-100 compliant product specification for Bathymetric Surface Products. Much of this document has been adapted from the Format Specification Document – Description of the Bathymetric Attributed Grid Object (BAG) Version 1.0.0 [2] Compliance with the S-102 product specification implies logical compliance with the BAG as specified by the Open Navigation Surface Project.

Bathymetric Surface data may be used alone or it may be combined with ENC or other S.100 compatible data. As such the Bathymetric Surface product specification serves as one of the layers that may be integrated using the mechanism described in **S.10x Auxiliary Information Layer Integration for use with ENC.** It inherits quadrilateral grid coverage structure form S.10x and S.100 Part 8. It also inherits the reference to a common tiling scheme, spatial referencing system, and other common system wide attributes described in S.10x.

This product specification also supports the separation of carrier and content as identified in the S.10x document. Both an HDF5 and a GeoTIFF plus XML encoding are included with future reference to a JPEG 2000 encoding.

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1 Scope

This document is a product specification for bathymetric surface data which may be use alone or as an auxiliary layer of data with an ENC. It specifies a navigation surface coverage including both depth and accuracy together with a point set of track changes that can form a conflated coverage that represents a navigation surface that may be certified by a hydrographer. The point set of tracking list changes allows the hydrographer to override selected grid value points to ensure a safety of navigation bias. This product specification includes a content model and separate encodings.

2 Conformance

Any data set claiming conformance with this IHO Standard shall pass all the requirements described in the abstract test suites in Appendix A.

3 Normative references

The following normative documents contain provisions that, through reference in this text, constitute provisions of this document.

IHO S.100 IHO Universal Hydrographic Data Model, Jan 2010
IHO S.44 Standards for Hydrographic Surveys 5th Edition, February 2008
IHO S.10x Auxiliary Information Layer Integration for use with ENC
ISO 8601:2004 Data elements and interchange formats _ Information interchange _ Representation of dates and times
ISO/TS 19103:2005 Geographic information - Conceptual schema language
ISO 19111:2003 Geographic information - Spatial referencing by coordinates
ISO 19115:2003 Geographic information - Metadata
ISO 19115-2:2009 Geographic information - Metadata: Extensions for imagery and gridded data
ISO 19123:2005 Geographic information - Schema for coverage geometry and functions
ISO 19129:2009 Geographic information - Imagery gridded and coverage data framework
ISO 19131:2007 Geographic information - Data product specifications
ISO/IEC 19501:2005, Information technology — Open Distributed Processing - Unified Modelling Language Version 1.4.2
Note: a summary of UML is given in S.100 Part 1

4 Terms, and definitions

4.1 Terms and definitions

Terms and definitions have been taken from the normative references cited in clause 3. Only those which are specific to this document have been included and modified where necessary. Additional terms are defined in this document.

4.1.1 continuous coverage

coverage that returns different values for the same feature attribute at different **direct position**s within a single **geometric object** in its **spatiotemporal domain**
[ISO 19123]

4.1.2 coordinate

one of a sequence of numbers designating the position of a point in N-dimensional space
[ISO 19111]

4.1.3 coordinate reference system

coordinate system which is related to the real world by a datum
[ISO 19111]

4.1.4 coverage

feature that acts as a function to return values from its range for any direct position within its spatial, temporal, or spatiotemporal domain
[ISO 19123]

EXAMPLE Examples include a digital image, polygon overlay, or digital elevation matrix.

NOTE In other words, a coverage is a feature that has multiple values for each attribute type, where each direct position within the geometric representation of the feature has a single value for each attribute type.

4.1.5 coverage geometry

configuration of the domain of a coverage described in terms of coordinates
[ISO 19123]

4.1.6 depth

distance of a point from a chosen reference surface measured downward along a line perpendicular to that surface
[ISO 19111:2006]

NOTE Height is distinguished from elevation in that it is a directional measurement A depth above the reference surface will have a negative value.

4.1.7 direct position

position described by a single set of coordinates within a coordinate reference system
[ISO 19107]

4.1.8 domain

well-defined set
[ISO 19103]

NOTE Domains are used to define the domain set and range set of operators and functions.

4.1.9 evaluation

< coverage>
determination of the values of a **coverage** at a **direct position** within the **spatiotemporal domain** of the **coverage**
[ISO 19123]

4.1.10 feature

abstraction of real world phenomena
[ISO 19101]

NOTE A feature may occur as a type or an instance. Feature type or feature instance should be used when only one is meant.

4.1.11 feature attribute

characteristic of a feature
[ISO 19109]

NOTE A feature attribute type has a name, a data type and a domain associated to it. A feature attribute instance has an attribute value taken from the value domain of the feature attribute type.

4.1.12 function

rule that associates each element from a **domain** (source, or domain of the function) to a unique element in another domain (target, co-domain, or **range**)
[ISO 19107]

NOTE The range is defined by another domain.

4.1.13 geometric object

spatial object representing a set of **direct positions**
[ISO 19107]

NOTE A geometric object consists of a **geometric primitive**, a collection of geometric primitives, or a geometric complex treated as a single entity. A geometric object may be the spatial characteristics of an object such as a **feature** or a significant part of a feature

4.1.14 grid

network composed of two or more sets of **curves** in which the members of each set intersect the members of the other sets in a systematic way
[ISO 19123]

NOTE The curves partition a space into grid cells.

4.1.15 grid point

point located at the intersection of two or more curves in a **grid**
[ISO 19123]

4.1.16 height

distance of a point from a chosen reference surface measured upward along a line perpendicular to that surface
[ISO 19111:2006]

NOTE Height is distinguished from elevation in that it is a directional measurement.

4.1.17 LIDAR

an optical remote sensing technique that uses a laser pulse to determine distance.

NOTE LIDAR may be used to determine dept in shallow water areas.

4.1.18 navigation surface

data object representing the bathymetry and associated uncertainty with the methods by which those objects can be manipulated, combined and used for a number of tasks, including products in support of safety of navigation

4.1.19 range

<coverage>
set of values associated by a **function** with the elements of the **spatiotemporal domain** of a **coverage**
[ISO 19123]

4.1.20 record

finite, named collection of related items (objects or values)
[ISO 19107]

NOTE Logically, a record is a set of pairs <name, item >.

4.1.21 rectified grid

grid for which there is a linear relationship between the grid coordinates and the coordinates of an external coordinate reference system
[ISO 19123]

NOTE If the coordinate reference system is related to the earth by a datum, the grid is a georectified grid.

4.1.22 referenceable grid

grid associated with a transformation that can be used to convert grid coordinate values to values of **coordinates** referenced to an **external coordinate reference system**
[ISO 19123]

4.1.23 SONAR

a technique that used sound propagation through water to determine distance, primarily depth measurement.

4.1.24 spatiotemporal domain

<coverage>
domain composed of **geometric objects** described in terms of spatial and/or temporal **coordinates**
[ISO 19123]

NOTE The spatiotemporal domain of a **continuous coverage** consists of a set of **direct positions** defined in relation to a collection of geometric objects.

4.1.25 surface

connected 2-dimensional **geometric primitive**, representing the continuous image of a region of a plane
[ISO 19107]

NOTE The boundary of a surface is the set of oriented, closed curves that delineate the limits of the surface.

4.1.26 tiling scheme

a discrete grid coverage that is used to partition data into discrete edge matched sets called tiles

4.1.27 uncertainty

The interval (about a given value) that will contain the true value of the measurement at a specific confidence level
[IHO S44]

NOTE Errors exist and are the differences between the measured value and the true value. Since the true value is never known it follows that the error itself cannot be known. Uncertainty is a statistical assessment of the likely magnitude of this error.

4.1.28 vector

quantity having direction as well as magnitude
[ISO 19123]

NOTE A directed line segment represents a vector if the length and direction of the line segment are equal to the magnitude and direction of the vector. The term vector data refers to data that represents the spatial configuration of features as a set of directed line segments.

5 Symbols and abbreviated terms

5.1 Abbreviations

This product specification adopts the following convention for presentation purposes:

API	Application Programmer's Interface
BAG	Bathymetric Attributed Grid
DS	Digital Signature
DSS	Digital Signature Scheme
ECDIS	Electronic Chart Display Information System
ECS	Electronic Chart System
ENC	Electronic Nautical Chart
GML	Geography Markup Language
IHO	International Hydrographic Organization
LIDAR	Light Detection And Ranging
NS	Navigation Surface
ONS	Open Navigation Surface
PK	Public Key
SA	Signature Authority
SK	Secret Key
SONAR	Sound Navigation And Ranging
UML	Universal Modelling Language

5.2 Notation

In this document conceptual schemas are presented in the Unified Modelling Language (UML). Several model elements used in this schema are defined in ISO standards developed by ISO TC 211, or in IHO S-100. In order to ensure that class names in the model are unique ISO TC/211 has adopted a convention or establishing a prefix to the names of classes that define the TC/211

defined UML package in which the UML class is defined. Since the IHO standards and this product specification make use of classes derived directly from the ISO standards this convention is also followed here. In the IHO standards the class names are identified by the name of the standard, such as "S100" as the prefix optionally followed by the bialpha prefix derived from ISO. For the classes defined in this document the prefix is "S102". In order to avoid having multiple classes instantiating the same root classes, the ISO classes and S.100 classes have been used where possible; however, a new instantiated class is required if there is a need to alter a class or relationship to prevent a reverse coupling between the model elements introduced in this document and those defined in S.100 or the ISO model.

Table 1 - Sources of externally defined UML classes

Prefix	Standard	Package
CI	ISO 19115	Citation and Responsible Party
CV	ISO 19123	Coverage Core & Discrete Coverages
DQ	ISO 19115	Data Quality Information
DS	ISO 19115	Metadata Application Information
EX	ISO 19115	Metadata extent information
IF	ISO 19129	Imagery Gridded and Coverage Data Framework
LI	ISO 19115	Data Quality Information
MD	ISO 19115	Metadata entity set information
MI	ISO 19115-2	Metadata entity set imagery
S100	IHO S.100	IHO Standard for Hydrographic Data
S10x	IHO S.10x (proposed)	IHO Specification for Auxiliary Information Layer Integration for use with ENC
SC	ISO 19111	Spatial Referencing by Coordinates
SD	ISO 19130	Sensor Model

6 Overview

6.1 Title

S.102 - Bathymetric Surface Product Specification.

6.2 Reference date

Proposed draft 31 March 2010 - (date to be revised when document if finalized).

6.3 Responsible party

International Hydrographic Bureau.
4 quai Antoine 1er
B.P. 445
MC 98011 MONACO CEDEX
Telephone: +377 93 10 81 00
Telefax: + 377 93 10 81 40

6.4 Language

Data products conforming to this product specification are available in English and additionally in other national languages together with English. That is, English or English plus another language

or languages shall be used in the metadata associated with the set of grid values defining the bathymetry coverage.

6.5 Informal description of the data product

A Bathymetric Surface Data Product contains the grid data values required to define a coverage data set representing the bottom of the sea or other navigable waterway together with associated metadata. The coverage data include an additional point set of values called "track changes" that allows a hydrographer to correct and certify the data to ensure a safety of navigation bias, thus establishing an Open Navigation Surface (ONS). The data product may be use independently or as a part of a set of auxiliary data layers to be used with ENC data or other S.100 data. The metadata data and structure required to support the aggregation of a set of auxiliary data layers is described in S.10x.

A Bathymetric Surface Data Product may exist anywhere on the earth. There are no limitations to its extent. A particular supplier, such as a national hydrographic office, may establish its own series of ENC charts and auxiliary data that can be used together with these charts or with other S.100 data. These series may include Bathymetric Surface data. When used together with other data layers the requirement is that the reference system be the same or be directly convertible for all layers and that the tiling schemes align.

The Bathymetric Surface Data Product may be used for many purposes, but the primary purpose is as an aid to navigation. It forms the base data for an Open Navigation Surface.

Bathymetric Data is collected by hydrographic sounding techniques including SONAR and LIDAR techniques. The data is maintained by reissuing data sets corresponding to one or more tiles.

7 Specification scopes

7.1 Scope general

The Bathymetric Surface Data Product specification defines a content model and exchange file format for the exchange of bathymetric coverage data in support of the Open Navigation Surface concept. The coverage type is a quadrilateral grid coverage together with attributes known as a Bathymetric Attributed Grid (BAG).

A single BAG coverage object represents one contiguous area of the skin of the Earth at a single resolution, but can represent data at any stage of the process from raw grid to final product. The name Navigation Surface (NS) is reserved for a final product BAG destined specifically for safety-of-navigation purposes.

An Application Programmer’s Interface (API) exists which provides an abstraction from the underlying technologies as well as providing a set of methods for an application programmer to easily read and write data conforming to the BAG specification..

In order to support the certification of bathymetric data for a navigational surface a Digital Certification Block must be included with the BAG data.

Each data supplier, such as a national hydrographic office, may establish its own series of bathymetric data products that may be used independently or in conjunction with other auxiliary data layers.

7.2 Scope identification

Global

Note: "Global" means that this scope refers to all parts of this data product specifications.

7.3 Level

This scope refers to the following level according to the ISO 19115 standard:

006 - series.

7.4 Level name

BAG.

7.5 Extent

This section describes the spatial and temporal extent of the scope.

7.5.1 Extent description

BAG data are seamless between datasets and form a continuous coverage.

7.5.2 Geographic Extent

The geographic extent of this product specification is world wide. Producers, in particular national hydrographic offices, will establish the bounding box defining the geographic extent of the data series they produce.

7.5.3 Temporal Extent

The temporal extent of this product specification is unbounded. Producers, in particular national hydrographic offices, will establish the beginning and end dates defining the temporal extent of the data series they produce.

8 Data product identification

8.1 Title

S.102 Bathymetric Surface.

8.2 Alternate Title

BAG - Bathymetric Attributed Grid.

8.3 Abstract

The Bathymetric Surface Data Product consists of a set of grid value matrix values organized to form a quadrilateral grid coverage with associated metadata representing a bathymetric depth

model for an area of the sea, river, lake or other navigable water. The data set includes both depth measurement values and accuracy measures associated with the depth values. In addition a point set of "tracking list changes" allows a hydrographer to override any particular grid matrix value to deliberately bias the data for safety of navigation. That is, the data set can carry both measured depth information that may be used for scientific purposes as well as corrected depth information that may be used for navigation.

8.4 Purpose

The primary purpose of the Bathymetric Surface Data Product is to support safe navigation as an auxiliary aid to navigation that may be used together with an ENC. The secondary use is as an independent source of depth information that may be used for other purposes.

8.5 Topic category

Main topics for the product, as defined by the ISO 19115 MD_TopicCategoryCode:

006– elevation;

012– oceans;

014– inlandWaters

8.6 Spatial representation type

Type of spatial representation for the product, as defined by the ISO 19115 MD_SpatialRepresentationTypeCode:

002 - grid.

8.7 Spatial resolution

The spatial resolution, or the spatial dimension on the earth covered by the size of a pixel (nominal ground sample distance), varies according to the producer (hydrographic office).

8.8 Reference to product specification scope

Global

Note: "Global" means that this scope refers to all parts of this data product specifications.

9 Data content and structure

9.1 Description

The Navigation Surface concept used in the Bathymetric Surface Data Product requires that in addition to estimation of depth, an estimate of the uncertainty associated with the depth must be computed and preserved. In order to make the system suitable to support safety of navigation applications, there is a means to over-ride any automatically constructed depth estimates with ‘Hydrographer Privilege’, (essentially , a means to specify directly the depth determined by a human observer as being the most significant in the area - irrespective of any statistical evidence to the contrary). The overridden data are maintained in the Tracking List.

Figure 1 shows a high level overview of the structure of S.102. It shows that the Bathymetric Surface Data Product consists of a set of data comprising the Bathymetric Attributed Grid plus a Digital Certification Block. The Digital Certification Block is mandatory when the data product is produced for navigational purposes so that the user can trace the whether the data has been certified. The BAG consists of a version tag plus other metadata, together with a coverage consisting of elevation (depth) values and an uncertainty as two values in a record at each grid value point, as well as the tracking list.

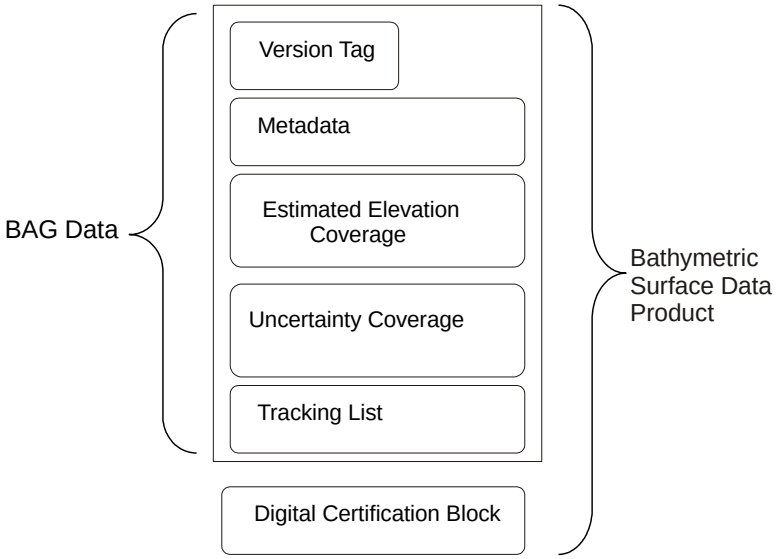

Fig 1 - Overview Structure of S.102

Thus, the Bathymetric Surface Data Product is a hybrid of coverage(s), as defined in IHO S-100 Part 8, and Information Types as defined in IHO S-100 Part 4, together with a point set Tracking List (which is discrete point set coverage that must be conflated with the depth and uncertainty coverage to have meaning). This is described in clause 9.2.

9.2 Coverage Information

9.2.1 Template Application Schema

The Application Schema for S.102 is a template application schema. That is, it does not resolve all attributes and allows some choice. This means that an implementer, such as a national hydrographic office, can produce another application schema as a profile of this application schema that makes additional choices. For example, the choice of whether to use a tiling scheme and which tiling scheme to use is left open. An implementer, such as a national hydrographic office, can select the tiling scheme, extent, resolution and other parameters most appropriate for their situation. Since the general structure is defined by the template Application Schema, common software that supports the S.102 template schema is able to support national and other more specific profiles.

The Application Schema Data Set Structure shown in Figure 2 derives from the general structure given in S.10x Auxiliary Information Layer Integration. It shows a number of classes specialized for use in S.102 and 7 implementation classes. An actual data set of S.102 bathymetry data only contains the implementation classes. All of the required attributes from the other classes in the

application schema are satisfied by statements within the product specification. This approach to producing the application schema[1] results in a very simple structure for implementation.

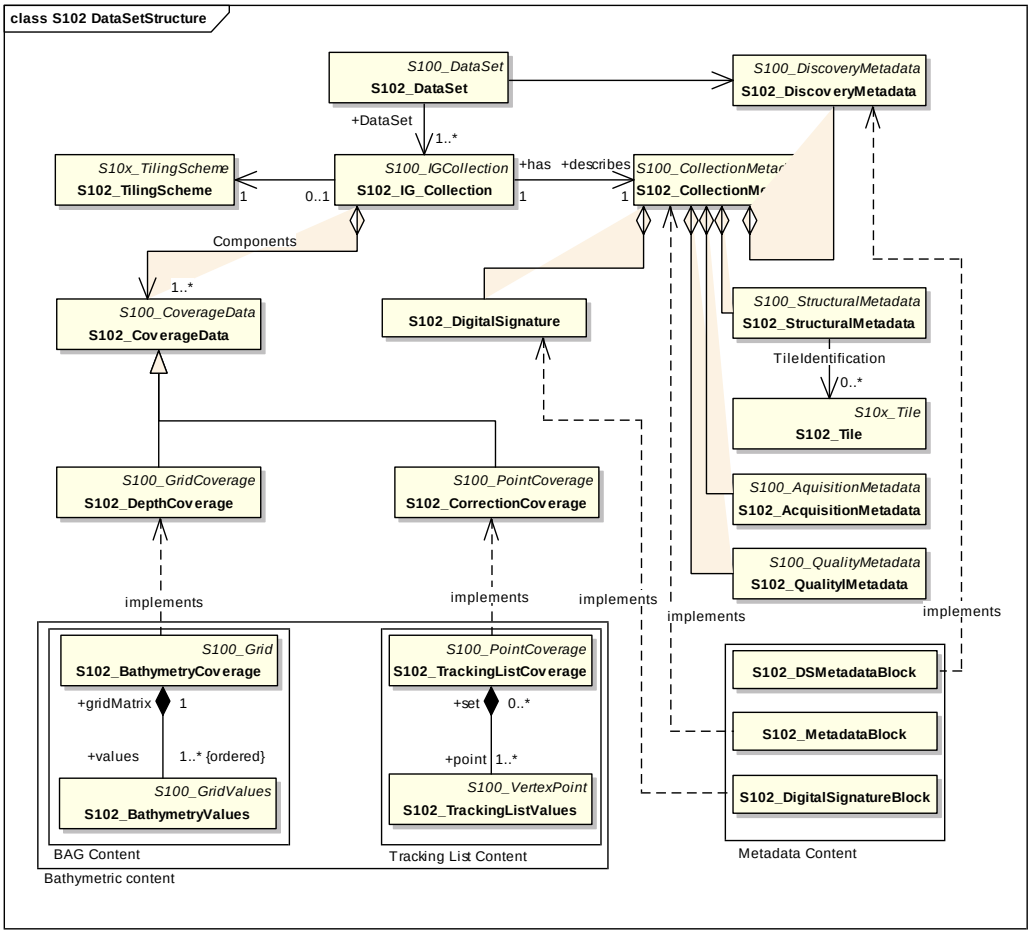

Fig 2 - Overview Structure of S.102

The model in Figure 2 states that:

> An S-102 data set (**S102_DataSet**), which is inherits from **S100_DataSet**, references an S-102 Image and Gridded Data Collection (**S102_IGCollection**). The relationship allows a 1 to many (**1..***) multiplicity which means that there may be multiple instances of S-102 data collections. Since each collection corresponds to a tile, this means that there may be multiple tiles in a data set[2]. The S-102 discovery metadata class (**S102_DiscoveryMetadata**) describes the metadata entities required for the identification of the entire data set. The required discovery metadata is implemented through the **S102_DSMetadataBlock** class.
>
> An instance of an S-102 Image and Gridded Data Collection (**S102_IGCollection**) which is a subtype of **S100_ IGCollection**, is described by a set of S102 Collection Metadata (**S102_CollectionMetadata**). This relationship is 1 to 1 meaning that there is one set of collection metadata for each instance of **S102_IGCollection**. There is a large choice of

[1] This approach to producing the application schema also means that the implementation is very similar to the structure supported by earlier versions of the BAG as proposed by the Open Navigation Surface project from the Center for Coastal and Ocean Mapping at the University of New Hampshire.

[2] Note that this is less general than the structure permitted in S.10x, but is sufficient for this data product.

metadata that may be used in a S.100 compliant data product. Only a small amount of this metadata is mandated by ISO 19115 for discovery. The choice of metadata is discussed in clause 9.2.5. Much of the metadata can be resolved as part of the product specification. Only that metadata that varies IG_collection item to item needs be included in the S102_MetadataBlock implementation class.

An S-102 Image and Gridded Data Collection also optionally makes reference to a tiling scheme. The details of the tiling scheme are normally defined in a product specification. This is discussed in clause 9.2.11. The metadata carries an ID that identifies a particular IG_Collection item as being one tile in a tiling scheme.

The class **S102_DigitalSignature** contains an encrypted function derived from the **S102_CoverageData** which may be used to verify the authenticity of the data. The use of a Digital Signature is optional at the S102 template application schema level, but it is normally mandatory in a specific profile in order to ensure traceability of authenticity for information used for navigation. Data complying with this template application schema could be used for other purposes so the usage of the capability is not mandatory at this level. However, systems that claim to support S102 are required to support the digital signature capability.

The metadata also refers to the coordinate reference system.

There are two coverage types in this application schema. The first is a continuous Quadrilateral Grid Coverage called **S102_DepthCoverage** which is inherits from (**S100_GridCoverage**). Many of the parameters of the coverage are described in the product specification. An implementation class **S102_BathymetryCoverage** is defined which inherits from **S100_Grid**.

The **S102_BathymetryCoverage** is composed of a ordered set of **S102_BathymetryValues**. Each value class instance contains a record that carries the depth value and the associated uncertainty. Both **S102_BathymetryCoverage** and **S102_BathymetryValues** are implementation classes.

The second coverage type discrete point set coverage called **S102_CorrectionCoverage**. This coverage consists of a set of discrete points that correspond to locations which need corrections. A hydrographer may explicitly specify depth values at specific points to deliberately ensure safety of navigation. The **S102_correction coverage** is used by conflating it with the **S102_BathymetryCoverage** to produce a corrected resultant coverage surface. A coverage function to determine depth would operate on the resultant conflated continuous mathematical surface. The conflation function simply replaces specific values from the S102_BathymetryValues grid values matrix with the corresponding overriding values.

9.2.2 Application Schema Implementation Classes

The seven implementation classes for the template application schema are shown in Figure 3. The attributes are shown for the coverage related classes together with the attribute classes.

In order to simplify the implementation a number of defaults are assumed for S102. These defaults mean that the implementation of the default case is very simple, and the implementation of a default form of an S.102 Bathymetric Surface Product Specification in HDF5 encoding is very similar to the original BAG implementation from the University of New Hampshire. However, S.102 does allow other values for these attributes so grids such as a Quad Tree could be used. In the following sub clauses the default values are emphasised so that they do not need to be encoded when generating an encoding of the implementation classes.

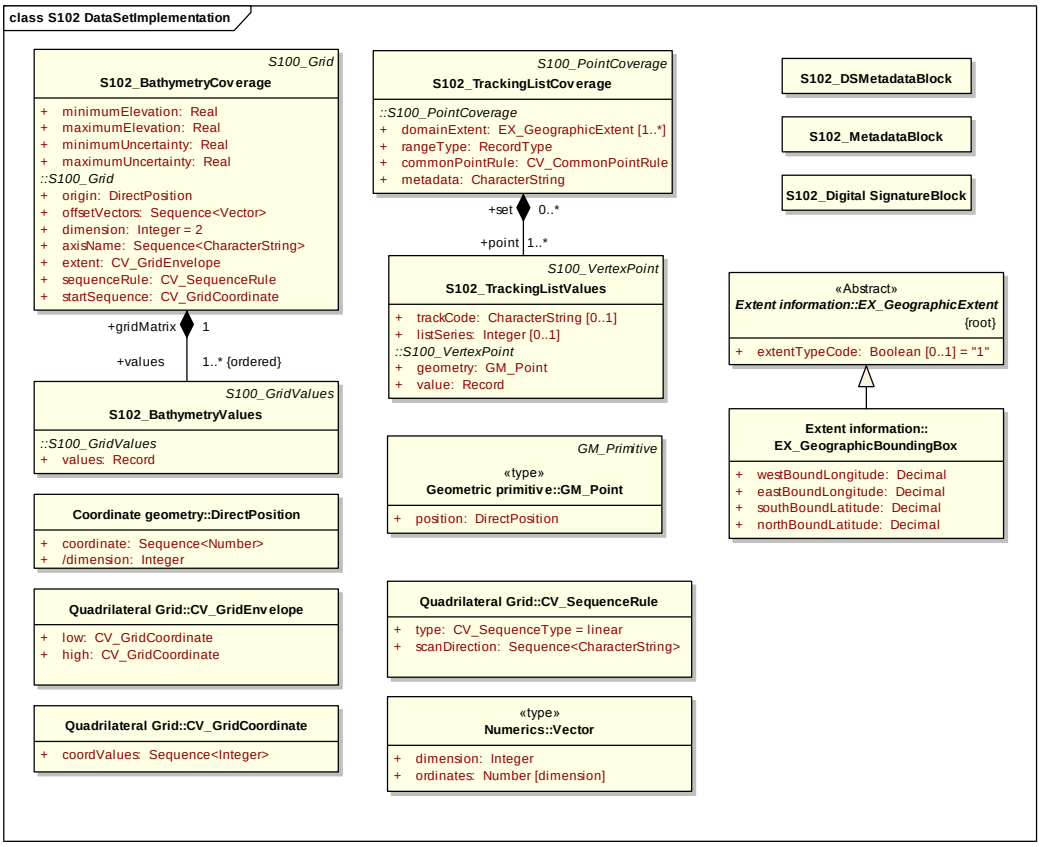

Fig 3 - Implementation Classes of S.102

9.2.3 Implementation Classes Description

9.2.3.1 S102_BathymetryCoverage

9.2.3.1.1 S102_BathymetryCoverage semantics

The class S102_BathymetryCoverage has the attributes *minimumElevation, maximumElevation, minimulUncertainity*, and *maximumUncertainity* which bound the *depthEstimate* attribute and the *uncertainity* attribute from the S102_BathymetryValues record and the inherited attributes *origin, offsetVectors, dimension, axisName, extent, sequenceRule*, and *startSequence* from S100_Grid and CV_Grid. The origin is a position in a specified coordinate reference system, and a set of offset vectors specify the direction and distance between the grid lines. It also contains the additional geometric characteristics of a rectified grid.

9.2.3.1.2 minimumElevation

The attribute *minimumElevation* has the value type *Real* and describes the lower bound of the depth estimate for all the *depthEstimate* values in S102_BathymetryValues record. The minimum elevation for a bathymetric depth is the shallowest depth. This attribute is required. There is no default.

9.2.3.1.3 maximumElevation

The attribute *maximumElevation* has the value type *Real* and describes the upper bound of the depth estimate for all the *depthEstimate* values in S102_BathymetryValues record. The maximum elevation for a bathymetric depth is the deepest depth. This attribute is required. There is no default.

9.2.3.1.4 minimumUncertainty

The attribute *minimumUncertainty* has the value type *Real* and describes the lower bound of the uncertainty of the depth estimate for all the *depthEstimate* values in S102_BathymetryValues record. This attribute is required. There is no default.

9.2.3.1.5 maximumUncertainty

The attribute *maximumUncertainty* has the value type *Real* and describes the upper bound of the uncertainty of the depth estimate for all the *depthEstimate* values in S102_BathymetryValues record. This attribute is required. There is no default.

9.2.3.1.6 origin

The attribute *origin* has the value class *DirectPosition* which is a position that shall locate the origin of the rectified grid in the coordinate reference system. This attribute is required. There is no default.

9.2.3.1.7 offsetVectors

The attribute *offsetVectors* has the value class *Sequence*<*Vector*> that shall be a sequence of offset vector elements that determine the grid spacing in each direction. The data type Vector is specified in ISO/TS 19103. This attribute is required. There is no default.

9.2.3.1.8 dimension

The attribute *dimension* has the value class *Integer* that shall identify the dimensionality of the grid. The value of the grid dimension in this product specification is 2. This value is fixed in this product specification and does not need to be encoded.

9.2.3.1.9 axisName

The attribute *axisName* has the value class *Sequence*<*CharacterString*> that shall be used to assign names to the grid axis. The grid axis names are by default "Latitude" and "Longitude" but may be different if, for example, the grid is at a different orientation.

9.2.3.1.10 extent

The attribute *extent* has the value class *CV_GridEnvelope* that shall contain the extent of the spatiotemporal domain of the coverage. It uses the value class *CV_GridEnvelope* which provides the grid coordinate values for the diametrically opposed corners of the grid. The default is that this value is derived from the bounding box for the data set or tile in a multi tile data set.

9.2.3.1.11 sequenceRule

The attribute *sequenceRule* has the value class *CV_SequenceRule* that shall describe how the grid points are ordered for association to the elements of the sequence values. The default value is "Linear".

9.2.3.1.12 startSequence

The attribute *startSequence* has the value class *CV_GridCoordinate* that shall identify the grid point to be associated with the first record in the values sequence. The default value is the lower left corner of the grid.

9.2.3.2 S102_BathymetryValues

9.2.3.2.1 S102_BathymetryValues semantics

The class S102_BathymetryValues is related to S102_BathymetryCoverage by a composition relationship in which an ordered sequence of bathymetry values provide data values for each grid cell. The class S102_BathymetryValues inherits from S100_Grid.

9.2.3.2.2 values

The attribute *value* has the value class *Record* which is a sequence of value items that shall assign values to the grid point. There are two values in each record in the S102_BathymetryValues class. These are the ***depthEstimate*** value and the ***uncertainty*** value. Figure 4 shows the record structure.

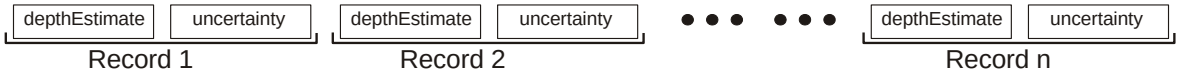

Fig 4 - Bathymetry Values Record Structure

9.2.3.3 DirectPosition

9.2.3.3.1 DirectPosition semantics

The class DirectPosition hold the coordinates for a position within some coordinate reference system.

9.2.3.3.2 coordinate

The attribute *coordinate* is a sequence of Numbers that hold the coordinate of this position in the specified reference system.

9.2.3.3.3 dimension

The attribute *dimension* is a derived attribute that describes the length of coordinate.

9.2.3.4 Vector

9.2.3.4.1 Vector semantics

The class Vector is an ordered set of numbers called coordinates that represent a position in a coordinate system..

9.2.3.4.2 dimension

The attribute *dimension* is a derived attribute that describes the length of the sequence of vector ordinates.

9.2.3.4.3 ordinates

The attribute *ordinates* is a sequence of Numbers that hold the coordinate of this position in the specified reference system.

9.2.3.5 CV_GridEnvelope

9.2.3.5.1 CV_GridEnvelope semantics

The class CV_GridEnvelope provides the grid coordinate values for the diametrically opposed corners of an envelope that bounds a grid. It has two attributes.

9.2.3.5.2 low

The attribute *low* shall be the minimal coordinate values for all grid points within the envelope.

9.2.3.5.3 high

The attribute *high* shall be the maximal coordinate values for all grid points within the envelope.

9.2.3.6 CV_GridCoordinate

9.2.3.6.1 CV_GridCoordinate semantics

The class CV_GridCoordinate is a data type for holding the grid coordinates of a CV_GridPoint

9.2.3.6.2 coordValues

The attribute *coordValues* has the value class *Sequence* <*Integer*> τηατ shall hold one integer value for each dimension of the grid. The ordering of these coordinate values shall be the same as that of the elements of *CV_Grid.axisNames*. The value of a single coordinate shall be the number of offsets from the origin of the grid in the direction of a specific axis

9.2.3.7 CV_SequenceRule

9.2.3.7.1 CV_SequenceRule semantics

The class CV_SequenceRule that contains information for mapping grid coordinates to a position within the sequence of records of feature attribute values. It has two attributes.

9.2.3.7.2 type

The attribute *type* shall identify the type of sequencing method that shall be used. A code list of scan types if provides in S.100 Part 8 and in ISO 19123 Annex C. Only the value “linear” shall be used in S.102, which describes scanning row by row by column.

9.2.3.7.3 scanDirection

The attribute *scanDirection* has the value class *Sequence<CharacterString>* a list of axis names that indicates the order in which grid points shall be mapped to position within the sequence of records of feature attribute values. The default scan direction for a bathymetry grid in S.102 is "Latitude" and "Longitude".

9.2.3.8 S102_TrackingListCoverage

9.2.3.8.1 S102_ TrackingListCoverage semantics

The class S102_TrackingListCoverage has the attributes *domainExtent, rangeType,CommonPointRule* and *metadata* inherited from S100_PointSet. The S102_TrackingList coverage is a discrete point coverage which is used to correct the S102_BathymetryCoverage by allowing a hydrographer to apply a bias for safety of navigation. There are four defined attributes. The attribute *metadata* provides one method of linking the metadata to the coverage inherited from S100, however it is not required in S.102 because there is no need for specific metadata at the feature (class) level. The attribute commonPoinRule is also not required because the value has been established for the whole of the S102 data product to be "low" (less depth, less negative elevation) to ensure a bias for safety of navigation. The attribute *rangeType* takes on the value class *RecordType*. This is modelled by the composition of multiple instances of S.102_TrackingListValues. Therefore only the attribute *domainExtent* is required, and it has a default value.

Note: An attribute describing the length of the tracking list is not required in the content model, since this information can be derived from the instantiation of the model. However, such a count may exist within an encoding to support the encoding structure.

9.2.3.8.2 domainExtent

The attribute *domainExtent* has the value class *EX_GeographicExtent* which describes the spatial boundaries of the Tracking List elements within the bounds established by CV_GridEnvelope for the S102_BathymetryGrid. The default is the bounds established by the attribute CV_GridEnvelope.

9.2.3.9 S102_TrackingListValues

9.2.3.9.1 S102_TrackingListValues semantics

The class S102_TrackingListValues has the attributes *trackCode* and *ListSeries* and the attributes *geometry,* and *value* inherited from S100_VertexPoint and CV_GeometryValuePair. The tracking list is a discrete coverage used to furnish a set of values that may override values in the S102_BathymetryValues class. In order to assure alignment of tracking list values with the grid cells in the bathymetry coverage grid, the reference system for the tracking list is the bathymetry coverage quadrilateral grid.

The *trackCode* value and the *listSeries* value provide context for the override of a value from the bathymetry coverage. The *trackCode* value is a text string that describes the reason for the override of the and the *listSeries* value

9.2.3.9.2 trackCode

The optional attribute *trackCode* has the value type *CharacterString* which may contain a text string describing the reason for the override of the corresponding *depth* and *uncertainty* values in the bathymetry coverage.

9.2.3.9.3 listSeries

The optional attribute *listSeries* has the value type *Integer* which may contain an index number into a list of metadata elements describing the reason for the override of the corresponding *depth* and *uncertainty* values in the bathymetry coverage.

9.2.3.9.4 geometry

The attribute *geometry* has the value class *GM_Point* which is a position that shall locate the tracking list value. When the S102_TrackingListCoverage discrete coverage and the S102_BathymetryCoverage are conflated the values that are overridden in the sequence of the attribute S102-BathymetryValues are located by position. The value class is GM_Point which is a coordinate in related to the reference system of the bathymetry coverage quadrilateral grid.

9.2.3.9.5 values

The attribute *value* has the value class *Record* which is a sequence of value items that shall assign values to the discrete grid point. There are two values in each record in the S102_ TrackingListValues class. These are the *depth* value and the *uncertainty* value. The *depth* value and the *uncertainty* value may override the corresponding the *depth* and *uncertainty* values in the S102_BathymetryValues class record item when the S102_TrackingListCoverage discrete coverage and the S102_BathymetryCoverage are conflated. GM_Point

9.2.3.9.6 GM_Point semantics

The class GM_Point is taken from ISO 19107 and is the basic data type for a geometric object consisting of one and only one point. It has one attribute.

9.2.3.9.7 position

The attribute *position* is derived from DirectPosition for the geometry primitive GM_Point. In order to assure alignment of tracking list values with the grid cells in the bathymetry coverage grid, the reference system for the tracking list is the bathymetry coverage quadrilateral grid. This means that the *position* attribute corresponds to a grid cell. For a uniform quadrilateral grid this is the row and column of the grid position. For a more complex grid, such as a Quad Tree, it is the grid cell number derived from the Morton order[3].

[3] The grid cell number derived from the Morton order for a Quad Tree quadrilateral grid or multidimensional Hyperspatial grid is called the HHCode.

9.2.3.10 EX_GeographicExtent

9.2.3.10.1 EX_GeographicExtent semantics

The class EX_GeographicExtent is a metadata class from ISO 19115. It is a component of the metaclass EX_Extent. The use of EX_Extent is optional. When used it describes the spatial boundaries of the Tracking List elements within the bounds established by CV_GridEnvelope for the S102_BathymetryGrid. That is, the tracking list may carry information corresponding only to a portion of the spatial extent covered by the S102_BathymetryGrid. There is one attribute and one subtype.

9.2.3.10.2 ExtentTypeCode

The attribute *extentTypeCode* is a Boolean value. It is used to indicate indication of whether the bounding polygon/box encompasses an area covered by the data or an area where data is not present. In S102 it is set to 1.

9.2.3.11 EX_BoundingBox

9.2.3.11.1 EX_ BoundingBox semantics

The class EX_ BoundingBox is a metadata class from ISO 19115. It is a subtype of the abstract class EX_GeographicExtent. It defines a bounding box used to indicate the spatial boundaries of the Tracking List elements within the bounds established by CV_GridEnvelope for the S102_BathymetryGrid. It has four attributes.

9.2.3.11.2 westBoundLongitude

The attribute *westBoundLongitude* is a coordinate value providing the west bound longitude for the bound.

9.2.3.11.3 eastBoundLongitude

The attribute *eastBoundLongitude* is a coordinate value providing the east bound longitude for the bound.

9.2.3.11.4 southBoundLatitude

The attribute southBoundLatitude is a coordinate value providing the south bound longitude for the bound.

9.2.3.11.5 northBoundLatitude

The attribute northBoundLatitude is a coordinate value providing the north bound longitude for the bound.

9.2.4 Digital Signature Block Implementation Class

In a traditional hydrographic processing workflow, there is a strict chain of custody for all data that is to be used for nautical charting. At each stage of the chain, a responsible authority reviews the data, the processes applied to it, and certifies that the data is fit for some intended purpose. This may be that the data are ready for final plotting, that they are ready to be combined with other data in a compilation, or that the compilation is suitable as an aid to safe navigation. Generally, this is

done by some physical signature on appropriate archival documentation, which was traditionally the hydrographic smooth sheet or fair sheet.

With an all-digital product, however, there is no opportunity to affix a physical signature to the data object. In addition, with a dense data object such as a Bathymetric Surface product, the opportunity for single -bit errors in transmission to cause navigationally significant changes to the data which are otherwise undetectable is greatly increased. The Digital Signature Scheme (DSS) is designed to provide an equivalent analogue for the physical hydrographer's signature, and to ensure that any modifications to the data, either by mistake or malicious action, are readily detectable.

The S102_DigitalSignatureBlock is an implementation class corresponding to the class S102_DigitalSignature. It is an component of the S102_CollectionMetada.

The basic entity of the DSS is the Digital Signature (DS), a multi-byte sequence of digits computed from the contents of the S102_BathymetricCoverage and S102_TrakingListCoverage implementation classes and their components, the set of S102_BathymetricValues classes and the set of S102_TrakingListValues. This is indicated as "Bathymetric Content" in Figure 2. The Digital Signature also contains another number, known as the secret key (SK), belonging to the person or entity signing the Bathymetric Surface product, known as the Signature Authority (SA). The SK is known only to the SA, and as the name suggests should be kept confidential since knowledge of the SK would allow anyone to certify Bathymetric Surface products as if they were the SA. The DS value can be shown to be probabilistically unique for the contents of the "Bathymetric Content" and the SK in the sense that, with vanishingly small probability, no two BAGs would generate the same DS with a particular SK, and no two SKs would generate the same DS with the same "Bathymetric Content".

Corresponding to the SK, there is a public key (PK) that can be distributed freely. There is no way to compute the DS using the PK. However, given a "Bathymetric Content" and a DS purported to have been constructed with the SK, it is simple to verify whether the "Bathymetric Content" has changed, or if another SK was used to construct the certification.

In addition to the basic DS required for the DSS, the BAG certification block contains a link the certification event with an entry in the metadata's lineage section which describes the reasons for certification. The intent of this is to ensure that the user can provide suitably flexible descriptions of any conditions attached to the certification event, or the intended use of the data so certified. This 'Signature ID' shall be a file-unique sequentially constructed identifier so that a certification block can be unambiguously associated with exactly one lineage element.

The structure of the Digital Signature Block is encoding dependent.

9.2.5 Metadata

The Metadata elements used in the Bathymetric Surface product are derived from S.100 and S.10x and from ISO 19115 and ISO 19115-2[4]. Optionally additional metadata may be derived from ISO 19130 and ISO 19130-2 especially metadata relating to the SONAR equipment which may have been used to acquire the bathymetric data.

There are only a few elements in the ISO 19115 metadata standard that are mandatory and these relate only to the use of the metadata for identification of the data set to assist in data discovery. A minimum level of data identification is required for all applications including database applications, web services and data set production.

[4] ISO 19130-2 Sensor Data Models Part 2 is under development in ISO TC211 and will address SONAR sensor metadata.

The elements are related in a metadata schema, and include definitions and extension procedures. There exist both mandatory and conditional metadata elements. Only a few metadata elements are mandatory but the inclusion of some of the optional metadata elements establish a situation where other metadata elements are conditionally made mandatory.

The following table outlines the core metadata elements (mandatory and recommended optional) required for describing a geographic information data set. The codes indicate: "M" mandatory, "O" optional' "C" conditional as defined in ISO 19115. The table indicates how the mandatory and conditional core metadata is handled in S.102.

Table 2 - ISO TC211 Core Metadata as applied in S.102

Dataset title (M) S102_DS_DiscoveryMetadata > citation > CI_Citation.title from: (MD_Metadata > MD_DataIdentification.citation > CI_Citation.title)	**Spatial representation type** (O) S102_DS_DiscoveryMetadata > spatialRepresentationType : MD_ SpatialRepresentationType Code 002– Grid; (for quadrilateral grid coverage) 001– Vector; (for tracking list discrete point coverage) from: (MD_Metadata > MD_DataIdentification.spatialRepresentationType)
Dataset reference date (M) S102_DS_DiscoveryMetadata > citation > CI_Citation.date from: (MD_Metadata > MD_DataIdentification.citation > CI_Citation.date)	**Reference system** (O) S102_StructureMetadataBlock > hRefSystem and S102_StructureMetadataBlock > vRefSystem from: (MD_Metadata > MD_ReferenceSystem)
Dataset responsible party (O) S102_DS_DiscoveryMetadata > pointOfContact > CI_ ResponsibleParty from: (MD_Metadata > MD_DataIdentification.pointOfContact > CI_ResponsibleParty)	**Lineage** (O) S102_QualityMetadataBlock > S102_LI_Source and S102_QualityMetadataBlock > S102_LI_ProcessStep from: (MD_Metadata > DQ_DataQuality.lineage > LI_Lineage)
Geographic location of the dataset (by four coordinates or by geographic identifier) (C) S102_DS_DiscoveryMetadata > extent > EX_Extent from: (MD_Metadata > MD_DataIdentification.extent > EX_Extent > EX_GeographicExtent > EX_GeographicBoundingBox or EX_GeographicDescription)	**On-line resource** (O) (MD_Metadata > MD_Distribution > MD_DigitalTransferOption.onLine > CI_OnlineResource) Optional - not required
Dataset language (M) S102_DS_DiscoveryMetadata > language from: (MD_Metadata > MD_DataIdentification.language)	**Metadata file identifier** (O) (MD_Metadata.fileIdentifier) Implicit in S1.02 product specification reference to ISO 19115 as a normative reference
Dataset character set (C) set to default = "utf8". [not required when set to default from ISO 19115] from: (MD_Metadata >	**Metadata standard name** (O) (MD_Metadata.metadataStandardName) Implicit in S1.02 product specification reference to ISO 19115 as a normative reference

MD_DataIdentification.characterSet)	
Dataset topic category (M) S102_DS_DiscoveryMetadata > topicCategory: MD_TopicCategoryCode 006– elevation; 012– oceans; 014– inlandWaters [see clause 8.5] from: (MD_Metadata > MD_DataIdentification.topicCategory)	**Metadata standard version** (O) (MD_Metadata.metadataStandardVersion) Implicit in S1.02 product specification reference to ISO 19115 as a normative reference
Spatial resolution of the dataset (O) (MD_Metadata > MD_DataIdentification.spatialResolution > MD_Resolution.equivalentScale or MD_Resolution.distance) Since this data set is a grid coverage resolution is defined by the coveraqe grid parameters.	**Metadata language** (C) (MD_Metadata.language) The language is set to English. In addition additional languages may be used in accordance with the structure for handling multi-languages per ISO 19115 Annex J.
Abstract describing the dataset (M) S102_DS_DiscoveryMetadata > abstract from: (MD_Metadata > MD_DataIdentification.abstract)	**Metadata character set** (C) set to default = "utf8". [not required when set to default from ISO 19115] from: (MD_Metadata.characterSet)
Distribution format (O) (MD_Metadata > MD_Distribution > MD_Format.name and MD_Format.version) Optional - not applicable to maintain the separation of carrier and content the content model does not contain any format information. This would be included in a transmittal or by file types.	**Metadata point of contact** (M) S102_DS_DiscoveryMetadata > contact from: (MD_Metadata.contact > CI_ResponsibleParty)
Additional extent information for the dataset (vertical and temporal) (O) (MD_Metadata > MD_DataIdentification.extent > EX_Extent > EX_TemporalExtent or EX_VerticalExtent) Optional - not required	**Metadata date stamp** (M) S102_DS_DiscoveryMetadata > dateStamp from: (MD_Metadata.dateStamp)

9.2.6 Product Specification Fixed Metadata

Some metadata elements derive from the content model. That is, certain attributes of classes taken from S.100 are set for the whole of S.102 and become product specification fixed metadata. Since S.102 addresses bathymetry coverages some information can be know from the type of product. These are the attributes that establish the common S.100_GridCoverage parameters. This information is established in the product specification and does not need to be part of the data exchange. The choices for these are discussed in S.10x. The two grid coverages attributes established for all of S.102 are given below:

The S100_GridCoverage attribute ***commonPointRule*** identifies a method for resolving potential conflicts between attribute values resulting from evaluation of a coverage at a direct position when that position falls on the boundary between two value objects, such the edge of two grid cells. For bathymetry the appropriate value would be **"low"**, meaning the lesser depth value, to ensure that depths are given at their shallowest value to promote safety of navigation.

The S100_GridCoverage attribute ***interpolationType*** describes the interpolation method recommended for evaluation of the GridCoverage. For bathymetry and similar data the value is either 'bilinear' or 'bicubic'. For S.102 the choice is " **Bilinear interpolation**".

> **Bilinear interpolation** is used to interpolate feature attribute values at direct positions within a quadrilateral grid using the function:
>
> $v = a_0 + a_1x + a_2y + a_3xy$

9.2.7 Discovery Metadata

Metadata is used for a number of purposes. One high level purpose if for the identification and discovery of data. Every data set needs to be identified so that it can be distinguished from other data sets and so it can be found in a data catalogue, such as a Web Catalogue Service. The discovery metadata applies at the S102_DataSet level and at the S102_collection level. That is, there is discovery data for the whole data set and for those data sets that are composed of several tiles there is also equivalent discovery metadata for each tile.

Figure 5 shows the S102_DiscoveryMetadataBlock. It has two subtypes S102_DS_DiscoveryMetadata and S102_Tile_DiscoveryMetadata. The only difference is that the hierachyLevel code is set to "dataset" for the whole data set and "tile" for a tile. These two classes implement the metadata classes from ISO 19115. First implementation classes have been developed corresponding to each of the ISO 19115 classes that have been referenced in which only the applicable attributes have been included. The classes S102_DS_DiscoveryMetadata and S102_Tile_DiscoveryMetadata inherit their attributes from these S.102 specific implementation classes. In addition an additional component S102_BAGDataIdentification has been added.

This model provides the minimum amount of metadata for a Bathymetry Surface data product. Any of the additional optional metadata elements from the source ISO 19115 metadata standard can also be included.

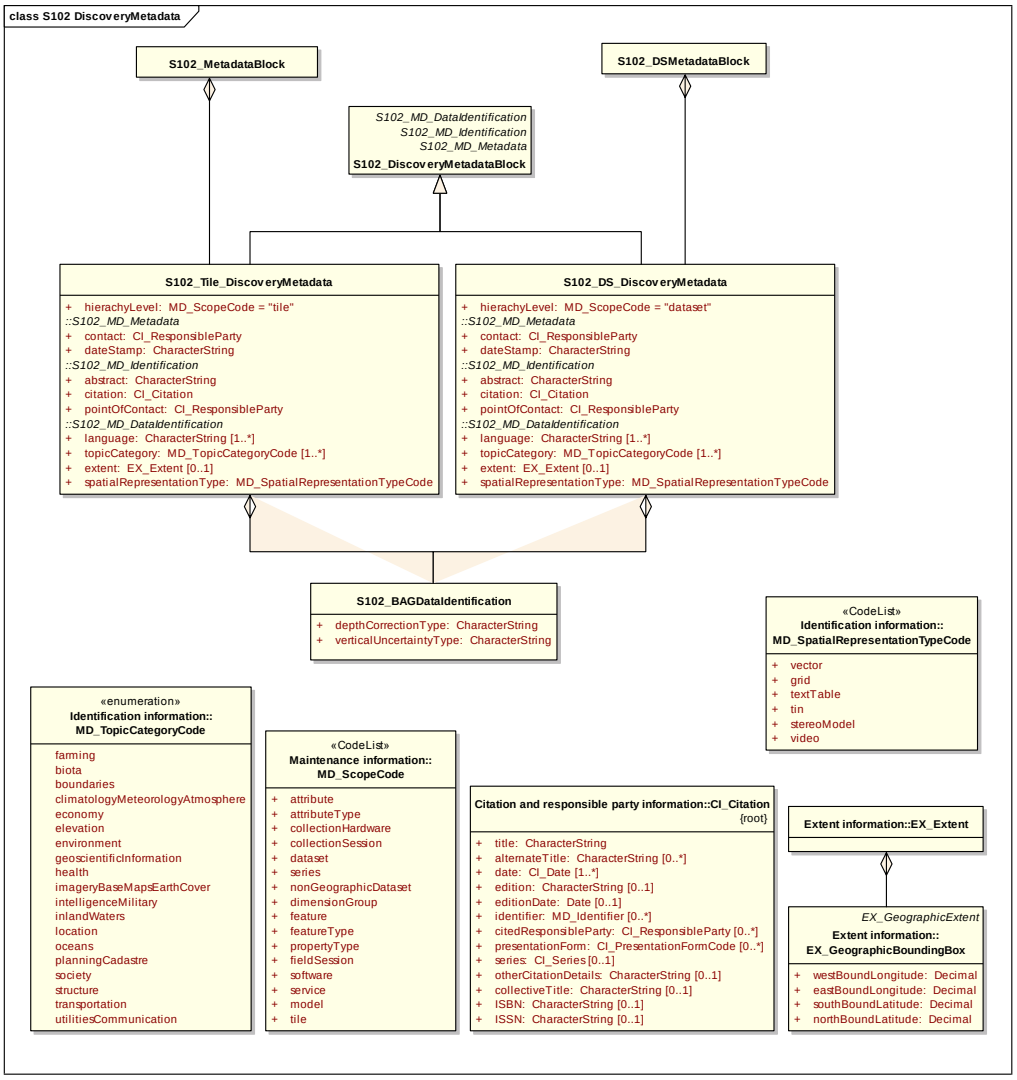

Fig 5 - S.102 Discovery Metadata Block

Table 3 provides a description of each attribute of the S102_DiscoveryMetadataBlock class attributes.

Table 3 - Discovery Metadata Block description

Role Name	Name	Description	Cardinality	Type	Remarks
Class	S102_DiscoveryMetadataBlock	Container class for discovery metadata	-	-	
Class	S102_DS_DiscoveryMetadata	Container class for discovery metadata related to an entire data set	-	-	
Class	S102_Tile_DiscoveryMetadata	Container class for discovery metadata related to a particular tile when there are multiple tiles in a data set.	-	-	
attribute	hierachyLevel		1	MD_ScopeCode	"dataset" for S102_DS_Discov

Role Name	Name	Description	Cardinality	Type	Remarks
					eryMetadata or "tile" for S102_Tile_DiscoveryMetadata
attribute	contact	party responsible for the metadata information	1	CI_ResponsibleParty	
attribute	dateStamp	date that the metadata was created	1	CharacterString	
attribute	abstract	brief narrative summary of the content of the resource(s)	1	CharacterString	
attribute	citation	citation data for the resource(s)	1	CI_Citation	CI_Citation <<DataType>> Required items are Citation.title, & Citation.date,
attribute	pointOfContact	identification of, and means of communication with, person(s) and organization(s) associated with the resource(s)	1	CI_ResponsibleParty	CI_ResponsibleParty <<DataType>>
attribute	language	language(s) used within the dataset	1-*	CharacterString	ISO 639-2 list of languages, default "English" plus others as used.
attribute	topicCategory	main theme(s) of the dataset	1-*	MD_TopicCategoryCode	MD_TopicCategoryCode <<Enumeration>> 006– elevation; 012– oceans; 014– inlandWaters
attribute	extent	extent information including the bounding box, bounding polygon, vertical, and temporal extent of the dataset	0-1	EX_Extent	EX_Extent <<DataType>>
attribute	spatialRepresentationType	method used to spatially represent geographic information	1	MD_SpatialRepresentationTypeCode	MD_SpatialRepresentationTypeCode <<CodeList>> 002– Grid; (for quadrilateral grid coverage) 001– Vector; (for tracking list discrete point coverage)
Class	S102_BAGDataIdentification	component for S102_DiscoveryMetadata Block. Extension beyond ISO 19115 metadata	-	-	
attribute	depthCorrectionType	code defining the type of sound velocity correction made to the depths	1	CharacterString	see table 4
attribute	verticalUncertaintyType	code defining how uncertainty was determined	1	CharacterString	see table 5

The class S102_BAGDataIdentification provides an extension to the metadata available from ISO 19115. The verticalUncertaintyType attribute was added to allow the BAG to accurately describe the source and meaning of the encoded Uncertainty coverage. The depthCorrectionType was also added to define if and how the elevations are corrected (i.e. true depth, depth ref 1500 m/sec, etc.). Tables 4 and 5 provide a description.

Table 4 - Code defining the type of sound velocity correction

Value	Definition
SVP_Applied	Sound velocity field measured and applied (True Depth).
1500_MS	Assumed sound velocity of 1500 m/s used.
1463_MS	Assumed sound velocity of 1463.04 m/s used (Equivalent to 4800 ft/s).
NA	Depth not measured acoustically.
Carters	Depths corrected using Carter's Tables.
Unknown	

Table 5 Code defining how uncertainty was determined

Value	Definition
Unknown	"Unknown" - The uncertainty layer is an unknown type
Raw_Std_Dev	"Raw Standard Deviation" - Raw standard deviation of soundings that contributed to the node.
CUBE_Std_Dev	Dev "CUBE Standard Deviation " - Standard deviation of soundings captured by a CUBE hypothesis (i.e., CUBE's standard output of uncertainty)
Product_Uncert	"Product Uncertainty" - NOAA standard product uncertainty V1.0 (a blend of CUBE uncertainty and other measures).
Historical_Std_Dev	"Historical Standard Deviation " – Estimated standard deviation based on historical/archive data.

9.2.8 Discovery Metadata

Structure metadata is used for a to describe the structure of an instance of a collection, including any reference to a tiling scheme and a Tile ID. Since constraints can be different on separate files (for example they could be derived from different legal sources), or security constraints may be different, the constraint oinformation becomes part of the structure metadata. The other structure metadata is the grid representation and the reference system.

Figure 6 shows the S102_StructureMetadataBlock. The metadata block is generated by the inheritance of attributes from a number of ISO 19115 metadata classes, and S.10x class for tileing and two implementation classes for the horizontal and vertical reference system. This makes the metadata block a simple table.

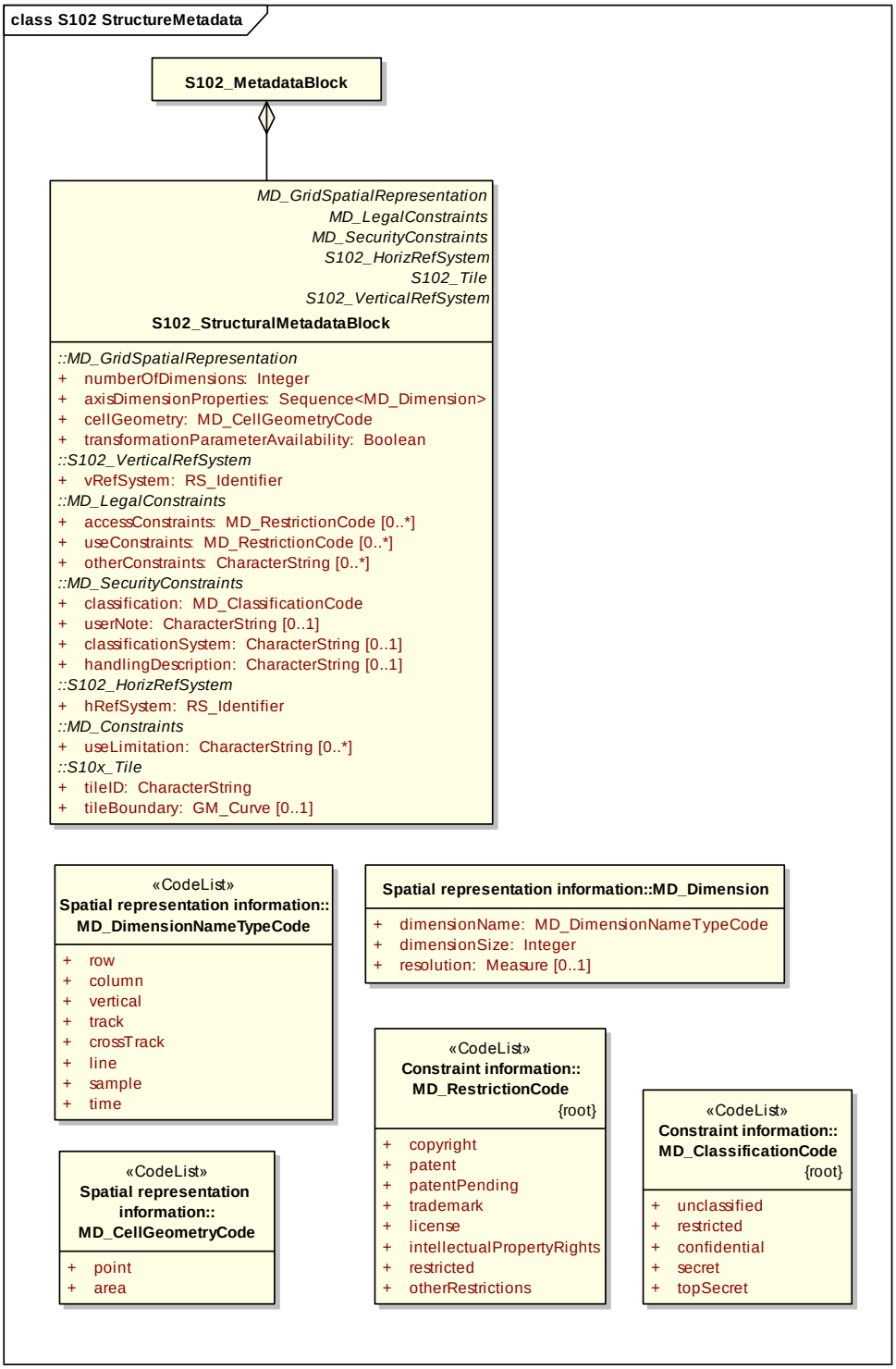

Fig 6 - S.102 Structural Metadata Block

Table 6 provides a description of each attribute of the S102_StructureMetadataBlock class attributes.

Table 6 - Structural Metadata Block description

Role Name	Name	Description	Cardinality	Type	Remarks
Class	S102_StructuralMetadataBlock	Container class for structural metadata	-	-	
attribute	numberOfDimensions	number of independent spatialtemporal axes	1	Integer	default = 2
attribute	axisDimensionProperties	information about spatial-temporal axis properties	1	MD_Dimension	MD_Dimension <<DataType>> dimensionName and dimensionSize
attribute	cellGeometry	identification of grid data as point or cell	1	MD_CellGeometryCode	MD_CellGeometryCode <<CodeList>>
attribute	TransformationParameterAvailability	indication of whether or not parameters for transformation between image coordinates and geographic or map coordinates exist (are available)	1	Boolean	1 = yes 0 = no
attribute	vRefSystem	name of vertical reference system	1	RS_Identifier	reference system vertical information, can also be defined explicitly by use of the parameters in 19111
attribute	hRefSystem	name of vertical reference system	1	RS_Identifier	default = WGS84. reference system horizontal information, can also be defined explicitly by use of the parameters in 19111.
attribute	accessConstraints	Access constraints applied to assure the protection of privacy or intellectual property, and any special restrictions or limitations on obtaining the dataset.	0-*	MD_RestrictionCode	
attribute	useConstraints	Constraints applied to assure the protection of privacy or intellectual property, and any special restrictions or limitations or warnings on using the dataset	0-*	MD_RestrictionCode	
attribute	otherConstraints	Other restrictions and legal prerequisites for accessing and using the dataset	0-*	CharacterString	
attribute	classification	Name of the handling restrictions on the dataset	1	MD_ClassificationCode	
attribute	userNote	Additional information about the classification	0-1	CharacterString	
attribute	classificationSystem	Name of the classification system	0-1	CharacterString	
attribute	handlingDescription	Additional information about the restrictions on	0-1	CharacterString	

Role Name	Name	Description	Cardinality	Type	Remarks
		handling the dataset			
attribute	tileID	tile identifier	1	CharacterString	
attribute	tileBoundary	tile boundary	0-1	GM_Curve	When not provided is assumed to be the extent of the collection as defined by EX_Extent
Class	MD_Dimension	Axis properties	-	-	
attribute	dimensionName	name of axis	1	MD_DimensionTypeCode	Defaults are "row" and "column"
attribute	dimensionSize	number of elements along the axis	1	Integer	
attribute	resolution	degree of detail in the grid dataset	0-1	Measure	value= number

9.2.9 Quality Metadata

Qulaity metadata is used to describe the quality of the data in an instance of a collection (which corresponds to one tile if multiple tiles are used). Quality may be different on different tiles.

Figure 7 shows the S102_QualityMetadataBlock. The S102_QualityMetadataBlock derives directly from the ISO 19115 class DQ_DataQuality. However its components S102_LI_Source and S102_LI_ProcessStep are generated by the inheritance of attributes from the ISO 19115 classe3s LI_Scope and LI_ProcessStep. Only some of he attributes of the referenced ISO 19115 classes are implemented. In addition the class S102_BagProcessStep has been added. This extension allows internal Tracking List entries to be associated with a unique entry in the metadata so that the changes can be properly attributed, described and easily referenced.

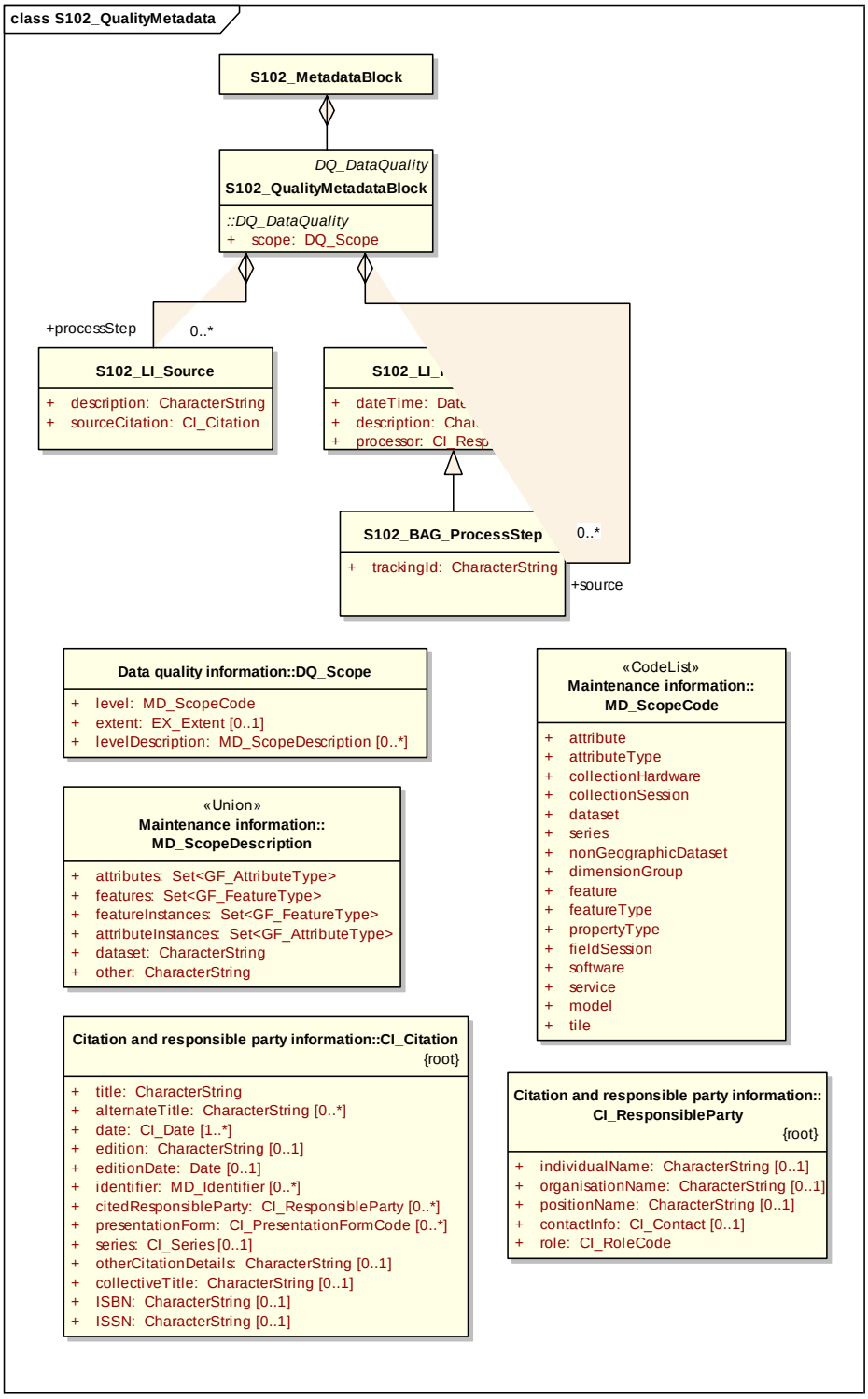

Fig 7 - S.102 Quality Metadata Block

Table 7 provides a description of each attribute of the S102_QualityMetadataBlock class attributes and those of its components.

Table 7 - Quality Metadata Block description

Role Name	Name	Description	Cardinality	Type	Remarks
Class	S102_QualityMetadataBlock	Container class for quality metadata	-	-	
attribute	scope	extent of characteristic(s) of the data for which quality information is reported	1	DQ_Scope	
Class	S102_LI_Source	information about the source data used in creating the data specified by the scope	-	-	
attribute	description	detailed description of the level of the source data	1	CharacterString	
attribute	sourceCitation	recommended reference to be used for the source data	1	CI_Citation	
Class	S102_LI_ProcessStep	information about an event or transformation in the life of a dataset including the process used to maintain the dataset	-	-	
attribute	dateTime	date and time or range of date and time on or over which the process step occurred	1	CharacterString	
attribute	description	description of the event, including related parameters or tolerances	1	CharacterString	
attribute	processor	identification of, and means of communication with, person(s) and organization(s) associated with the process step	1	CI_ResponsibleParty	
Class	S102_BAG_ProcessStep	Management of TrackingList references to LI_ProcessStep	-	-	
attribute	trackingId	ID reference used so that Tracking List entries can be associated with a unique entry in the metadata so that the changes can be properly attributed, described and easily referenced	1	CharacterString	
Class	DQ_Scope	Container class for qualityl metadata	-	-	
attribute	level	hierarchical level of the data specified by the scope	0-*	MD_ScopeCode <<CodeList>>	"dataset" or "tile"
attribute	extent	information about the horizontal, vertical and temporal extent of the data specified by the scope	0-*	EX_Extent <<DataType>>	Used only if the extent of the data is different that the EX_Extent given for the collection / tile
attribute	levelDescription	detailed description about	1	MD_ScopeDescription	

Role Name	Name	Description	Cardinality	Type	Remarks
		the level of the data specified by the scope		<<Union>>	

9.2.10 Acquisition Metadata

Acquisition metadata is optional in S.102. A producer or national hydrographic office may add acquisition metadata to a Bathymetric surface product specification profile that they are developing nationally. The classes derive from ISO 19115, 19115-2, 19130 and 19130-2. The later document 19130-2 contains description of sonar parameters.

9.2.11 Tiling Scheme

Tiling is a technique to decompose an area of interest into smaller more manageable chunks of data. Each tile for an S.102 Bathymetry data product is a complete bathymetry grid complete with a depth and uncertainty coverage and optional tracking list together with metadata that is edge matched to adjacent tiles.

A Tiling scheme is a second higher level discrete grid coverage where the tiles are the value items of the discrete coverage. As such a tiling scheme requires a complete description as a coverage.

The tiling scheme does not have to be described with the data set, but it is necessary that the data set be able to index into the tiling scheme, and that the tiling scheme be well documented and able to be referenced.

Figure 8 shows the S102_Tiling Scheme structure. This structure is inherited from S.10x. It is left general in order to accommodate different tiling schemes to be used by different data producers or national hydrographic offices.

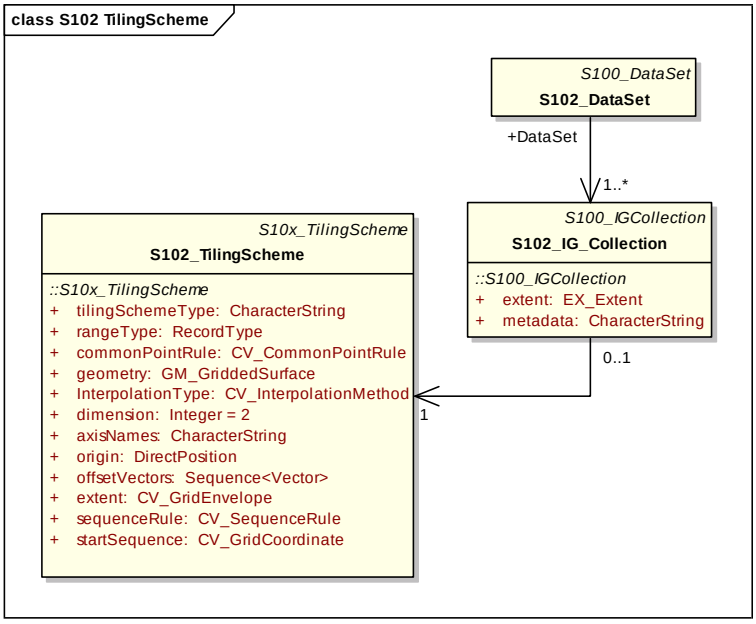

Fig 8 - S.102 Tiling Scheme

Table 8 provides a description of each attribute of the S102_TilingScheme class attributes.

Table 8 - Tiling Scheme description

Role Name	Name	Description	Cardinality	Type	Remarks
Class	S102_TilingScheme	Container class for tiling scheme description	-	-	
attribute	tilingSchemeType	description of the type of the tiling scheme	1	CharacterString	"uniform quadrilateral grid", or "Quad Tree" or other
attribute	domainExtent	description of the extent of the tiling scheme	1	EX_Extent	
attribute	rangeType	description of the range of the coverage	1	RecordType	the record value for each grid cell in a tiling scheme consists of a single entry corresponding to the tile,
attribute	commonPointRule	procedure to be used for evaluating the CV_Coverage at a position that falls on a boundary between tiles or within the boundaries of two or more overlapping tiles	1	CV_CommonPointRule	For tiles (not the data within a tile) the result is "all". That is, both tiles apply and are returned by a tiling scheme coverage function. The application will determine which to use.
attribute	geometry	geometry of the domain object	1	GM_GriddedSurface	
attribute	interpolationType	identification of interpolation method	1	CV_InterpolationMethod	not applicable, Tiles can not be interpolated
attribute	dimension	dimensionality of the grid	1	Integer	default = 2
attribute	axisNames	names of the grid axis	1	CharacterString	The grid axis names are by default "Latitude" and "Longitude" but may be different if, for example, the grid is at a different orientation.
attribute	origin	position that locates the origin of the rectified grid in the coordinate reference system	1	DirectPosition	
attribute	offsetVectors	a 2 dimensional vector quantity that determine the grid spacing in each direction	1	Sequence <Vector>	
attribute	extent	description of the extent of the tiling scheme	1	CV_GridEnvelope	
attribute	sequenceRule	describe how the grid points are ordered for association to the elements of the sequence values.	1	CV_SequenceRule	The default value is "Linear" which is used for a uniform quadrilateral grid tile coverage, or may be "Morton" for a Quad Tree
attribute	startSequence	the grid point to be	1	CV_GridCoordinate	The default value

Role Name	Name	Description	Cardinality	Type	Remarks
		associated with the first record in the values sequence			is the lower left corner of the grid

9.2.12 Feature Catalogue

A coverage is a type of feature so a Bathymetry Surface product specification does contain features. There are four coverages defined. The bathymetry depth coverage and the uncertainty coverage are combined into one continuous coverage with two entries in each value record. The third and fourth coverages are the discrete point coverages that corresponds to the tracking list of corrected values and uncertainties that may be conflated with the measured depth coverage and uncertainty coverage to produce a coverage biased to safety of navigation. These four entries compose the feature catalogue.

9.2.13 Reference to product specification scope

Global.

Note: "Global" means that this scope refers to all parts of this data product specifications.

9.3 BAG Coverages

The major components of the Bathymetric Surface product are the coverages. At a minimum a Bathymetric Surface product (called a Bathymetric Attributed Grid BAG) must have two coverages. The general structure of each is defined in IHO S-100 Part 8 as a georectified grid. Metadata defining the axes, dimensions, and geolocation parameters are found in the metadata in the MD_GridSpatialRepresentation and other classes defined in ISO 19115. Furthermore the two coverages are collocated. Each of these contains a two-dimensional matrix organized in row major order, and starting from the south-western most data point, where each value is defined to be at an exactly specified geographic point (node).

The units of the elevation values are meters, and the sign convention is for z to be positive for values above the vertical datum. The reference vertical datum for the BAG is one of the mandatory Metadata items. This sign convention follows directly from the right hand coordinate system definition that BAG adheres to.

The unknown state for elevation is defined to be 1,000,000.0 (1.0e6).

The uncertainty values are expressed as positive quantities at a node. As detailed in clause 9.2.3.1 the uncertainty grid supports multiple definitions of vertical uncertainty. This allows BAGs to span the expected range of data products from raw, full resolution grid to final compiled product. For example, a BAG at the stage of final survey data processing should contain uncertainty information germane to the survey data itself and intended to be used for information compilation. A BAG intended for navigational purposes would need to specify the overall uncertainty to the mariner – these two values for uncertainty may be quite different.

A recipient of a BAG file can refer to the uncertainty definition in the Metadata to gain an understanding of how the uncertainty was computed. The unknown state for uncertainty is defined to be 0.0.

9.4 Tracking List

The tracking list contains a simple list of the original elevation and uncertainty values from any node of the surface that has been modified to account for hydrographer over-rides of the basic surface definition (e.g., as originally computed by an algorithmic method). The tracking list dataset and corresponding information contained in the metadata exist to provide an audit trail record of changes made to the data by manual intervention.

9.5 Extensions

Bathymetric Surface product specification is extensible. This includes both extensions to the content model and to the encodings supporting the content model. Extensions are optional coverages and not required for a file to be qualified nor do they invalidate compliant product. Additional layers of information not related to the bathymetric scope of this product specification should be defined in separate S.100 and S.10x compliant layers.

9.6 Coordinate Reference Systems

9.6.1 Spatial Representation

All coverages in the Bathymetric Surface product specification are georectified, simple uniform quadrilateral grids as defined in IHO S-100 Part 8 or Quad Tree (Riemann Hyperspatial) quadrilateral grids. All coverages in one product must be the same type.

All S102 Bathymetric Surface product coverages shall be represented with a right-handed Cartesian coordinate system. This system shall have the x-axis oriented towards positive eastings (for projected grids), or east (for geographic grids), and y-axis oriented towards positive northings (for projected grids), or north (for geographic grids). These definitions imply that the z-axis for the sounding data is positive away from the center of mass of the earth (i.e., is positive up), rather than the usual hydrographic convention of positive down (i.e., deeper depths are larger numbers and negative depths are above datum). User-level code is free to make this reflection if required, but must write the data using the positive-up convention. In order to make this distinction clear, the term “elevation” is used for the vertical component of the BAG, rather than “depth”. The uncertainty component of the BAG shall have the same coordinate system as the elevation component, with the exception that the z-axis is unipolar, and therefore the concept of direction of positive increase is irrelevant.

The grid data in a S102 Bathymetric Surface coverage (either elevation or uncertainty, and any other surfaces that may be added) shall be organized as a uniform quadrilateral grid in row-major order from west to east, and south to north in the file or optionally in a Quad Tree (Riemann Hyperspatial) grid in the Morton order. For the uniform quadrilateral grid the first sample of the grid is the node at the southwest corner of the grid with location as specified by the georeferencing parameters, the second is one grid resolution unit to the east of that position and at the same northing or latitude, and the third is two grid resolution units to the east and at the same northing or latitude. For C columns in the grid, the (C+1)th sample in the grid is located one grid resolution unit to the north, but on the same easting, or longitude, as the first sample in the grid..

9.6.2 Coordinate Reference System

The geo-referencing for a S102 Bathymetric Surface product shall be node-based, referenced from the southwestern-most node in a grid. Each sample in a grid represents the value in the grid at a point location at the coordinate specified, rather than an estimate over any area with respect to the coordinate. The reference position included in the metadata shall be given in the coordinates used

for the grid, and shall contain sufficient digits of precision to locate the grid with accuracy no worse than a millimeter on the surface of the ellipsoid of rotation of the chosen horizontal datum.

The Coordinate Reference System Information is defined in the manner specified in s.100. The coverage can be specified in any projected coordinate system supported in the IHO S-100 Part 6 standard. However, no transformation methods are provided. Note the vertical datum is defined through a second association role to a vertical reference system.

9.6.3 Data Quality

As defined in IHO S-100 Part 4c the data quality for the elevation coverage is also defined as a co-located coverage, uncertainty. Uncertainty is defined as the vertical uncertainty at each node location. The uncertainty coverage supports multiple definitions of vertical uncertainty.

10 Data Capture

10.1 Description

There are a number of sounding techniques, including SONAR and LIDAR that are used to capture bathymetric data. It is permitted, but not required to include data acquisition information in the metadata of an S102 Bathymetric Surface product. The metadata class S102_AcquisitionMetadata has been defined, but the information elements to populate this metadata class must be identified in a national profile of S.102.

10.2 Reference to product specification scope

Global.

Note: "Global" means that this scope refers to all parts of this data product specifications.

11 Data Maintenance

11.1 Description

S.102 data sets are maintained by replacement on a tile basis. That is, the entire data product or tile within a data set including its coverages (elevation/depth, uncertainty, and tracking list point set coverage) an the associated metadata are replaces as a unit. This is unlike S.101 vector data that may be updated incrementally. However, coverage data must be considered as unit at least at the tile level. This is because processing is done on the entire tile to produce the data product. Any replacement tile will include its own tracking list (when a tracking list is used) to deliberately bias the information for safety of navigation. Also each replacement tile or data set must have its own digital signature.

11.2 Reference to product specification scope

Global.

Note: "Global" means that this scope refers to all parts of this data product specifications.

12 Encoding

12.1 Encoding Principals

ISO suite of geographic information standards is built on the concept of the separation of the "carrier" from the "content". This is reiterated in S.100 where several encoding approaches are identified. The content is defined in the product specification for any type of data, such as the S.102 bathymetry product specification, in terms of an encoding neutral UML model. Elements from this model are then used to create and Application Schema that is then encoded. Different layers of auxiliary data per S.10x, may have different encodings. Three separate encodings are identified for the S102 Bathymetric Surface product data. These are encodings using:

Hierarchical Data Format version 5 (HDF5);

GeoTIFF + XML; and

JPEG 2000 + XML.

The first encoding is described in Annex H and the second in Annex G. The possibility of using JPEG 2000 + XML is considered as a future longer term option, but is not yet viable until software tools become commonplace. It is possible, but probably not practical to develop a coding using ISO 8211 data descriptive file for information interchange standard. Not only are there no tools available to handle coverage data, but the standard is not widely used for this type of information, so there are not likely to be any such tools available.

Annex A
Abstract test suite

(normative)

This section needs to be developed. Discussions are needed to determine what needs to be tested.

A.1 Test case for

The .....

Annex B
Hierarchical Data Format Encoding

(normative)

Note: This encoding needs to be reviewed to ensure alignment with the revised Bathymetric Surface Product content model. In particular the metdata pertaining to coordinate referencing needs to be revised to align with the revised ISO 19111 and S.100.

B.1 Encoding Architecture

The Bathymetric Surface product utilizes the Hierarchical Data Format version 5 or HDF5 as one of its encodings. HDF5 is an architecture-independent software library and file format that allows for the storage and retrieval of large, complex datasets. HDF5 files are organized in a hierarchical structure, with two primary structures; groups and datasets.

An HDF5 “Group” provides the top-level structure for the data contents of the Bathymetric Surface product. The major subcomponents are defined using the HDF5 “Dataset” types, and “Attribute” types. Within each “Dataset”, further structural decomposition is specified via the DATATYPE and DATASPACE parameters. “Attributes” are included were appropriate to provide “Dataset” specific metadata. Following the high level file structure described in Figure 1, the specific HDF5 type definitions that define the BAG encapsulation structure are illustrated in Figure B1.

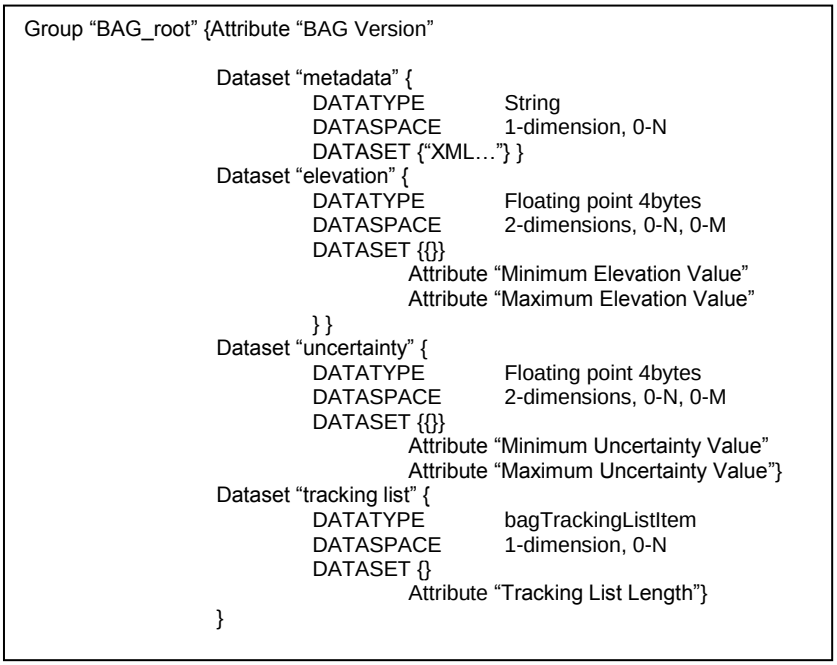

Fig B1 - Structure of BAG Data Encoding using HDF5

Table B1 provides a description the Bathymetric Surface product HDF5 encoding root group.

Table B1 - BAG Root Group

Entity Name	Data Type	Domain
BAG Version	String	Maximum 32 bytes available
Metadata	Dataset	Detailed in table 3
Elevation	Dataset	Detailed in table 4
Uncertainty	Dataset	Detailed in table 5
tracking list	Dataset	Detailed in table 6, and in table 7

Erreur ! Source du renvoi introuvable.6 defines the metadata items used within the BAG I/O library. These items must be present and properly defined for I/O operations to succeed. Note that this listing of metadata items does not specify the mandatory metadata items required by the ISO 19115 standard. The "XML Tag Nesting" Column specifies the XML element within the ISO 19139 implementation of ISO 19115 where the values are to be defined. The full schema is distributed in the source tree.

Table B2 - Group Level Metadata – Grid Parameters

Entity Name	XML Tag Nesting	Data Type	Domain
CoordSys			
Coordinate System code	Reference System Info/ projection/ Identifier/ code	Non Null String	Geodetic GEOREF Geocentric Local_Cartesian MGRS UTM UPS Albers_Equal_Area_Conic Azimuthal_Equidistant BNG Bonne Cassini Cylindrical_Equal_Area Eckert4 Eckert6 Equidistant_Cylindrical Gnomonic Lambert_Conformal_Conic Mercator Miller_Cylindrical Mollweide Neys NZMG Oblique_Mercator Orthographic Polar_Stereo Polyconic Sinusoidal Stereographic Transverse_Cylindrical_Equal_Area Transverse_Mercator Van_der_Grinten
Zone	Reference System	integer	[-60,-1] U [1,60]

	Info/ projection Parameters/ zone		
Standard Parallel	Reference System Info/ projection Parameters/ standard Parallel	Decimal Latitude	0 to 2 decimal numbers of range: [-90.0,+90.0]
Longitude Of Central Meridian	Reference System Info/ projection Parameters/ longitude Of Central Meridian	Decimal Longitude	range: [-180.0, +180.0]
Latitude Of Projection Origin	Reference System Info/ projection Parameters/ latitude Of Projection Origin	Decimal Latitude	range: [-90.0,+90.0]
False Easting	Reference System Info/ projection Parameters/ false Easting	Non Negative Decimal	[0.0, …), decimal is guaranteed at least 18 digits
False Northing	Reference System Info/ projection Parameters/ false Northing	Non Negative Decimal	[0.0, …), decimal is guaranteed at least 18 digits
False Easting Northing Units	Reference System Info/ projection Parameters/ false Easing Northing Units	Unit Of Measure	string
Scale Factor at Equator	Reference System Info/ projection Parameters/ scale Factor At Equator	Positive Decimal	[0.0, …)
Height of Perspective Point Above Surface	Reference System Info/ projection Parameters/ height Of Prospective Point Above Surface	Positive Decimal	[0.0, …)
Longitude of Projection Center	Reference System Info/ projection Parameters/ longitude Of Projection Center	Decimal Longitude	range: [-180.0, +180.0]
Latitude of Projection Center	Reference System Info/ projection Parameters/ latitude	Decimal Latitude	range: [-90.0,+90.0]

	Of Projection Center		
Scale Factor at Center Line	Reference System Info/ projection Parameters/ scale Factor At Center Line	Positive Decimal	[0.0, …)
Straight Vertical Longitude from Pole	Reference System Info/ projection Parameters/ straight Vertical Longitude From Pole	Decimal Longitude	range: [-180.0, +180.0]
Scale Factor at Projection Origin	Reference System Info/ projection Parameters/ scale Factor At Projection Origin	Positive Decimal	[0.0, …)
Oblique Line Azimuth Parameter	Reference System Info/ projection Parameters/ oblique Line Azimuth Parameter	Oblique Line Azimuth	AzimuthAngle, azimuthMeasurePointLongitude
Oblique Line Point Parameter	Reference System Info/ projection Parameters/ oblique Line Point Parameter	Oblique Line Point	obliqueLineLatitude, obliqueLineLongitude
Semi-Major Axis	Reference System Info/ Ellipsoid Parameters/ semi Major Axis	Positive Decimal	[0.0, …)
Axis Units	Reference System Info/ Ellipsoid Parameters/ axis Units	Unit Of Measure	String
Spatial Extent			
Horizontal Datum	Reference System Info/datum/ Identifier/ code	Non Null String	NAD83 – North American 1983 WGS72 – World Geodetic System 1972 WGS84 – World Geodetic System 1984
Number of Dimensions	Spatial Representation Info/ number Of Dimensions	Positive Integer	[0,1,2,…)
Resolution per Spatial Dimension	Spatial Representation Info/ Dimension/	Decimal	(0.0, 1.0e18) Guaranteed 18 digits with optional ‘.’, or leading signs, ‘+/-‘.

	resolution/value		
Size per Dimension	Spatial Representation Info/ Dimension/ dimension Size	nonnegative integer	[0,1,2,...,2^16-1]
Corner Points	Spatial Representation Info/ corner Points/ Point/ coordinates	Coordinates	1 to 4 points of pointPopertyType [-360.0,+360.0] decimal degrees
West Bounding Longitude	Data Identification/ extent/ geographic Element/ west Bound Longitude	Approximate Longitude	[-180.00, 180.00], maximum 2 fractional digits
East Bounding Longitude	Data Identification/ extent/ geographic Element/ east Bound Longitude	Approximate Longitude	[-180.00, 180.00], maximum 2 fractional digits
South Bounding Latitude	Data Identification/ extent/ geographic Element/ south Bound Latitude	Approximate Latitude	[-90.00, 90.00], maximum 2 fractional digits
North Bounding Latitude	Data Identification/ extent/ geographic Element/ north Bound Latitude	Approximate Latitude	[-90.00, 90.00] , maximum 2 fractional digits
Bag Metadata Extension			
Tracking List ID	Data Quality/ Lineage/ process Step/ tracking Id	Positive Integer	Short (2byte) integer
Vertical Uncertainty Type	Data Identification/ vertical Uncertainty Type	Character String	Unknown = 0, Raw_Std_Dev = 1, CUBE_Std_Dev = 2, Product_Uncert = 3, Historical_Std_Dev = 4

Table B3 Elevation Dataset Attributes

Entity Name	Data Type	Domain
Elevation	Float 32[][]	(FLT_MIN, FLT_MAX)
Minimum Elevation Value	Float 32	(FLT_MIN, FLT_MAX)
Maximum Elevation Value	Float 32	(FLT_MIN, FLT_MAX)

Table B4 Uncertainty Dataset Attributes

Entity Name	Data Type	Domain
Uncertainty	Float 32[][]	(FLT_MIN, FLT_MAX)
Minimum Uncertainty Value	Float 32	(FLT_MIN, FLT_MAX)
Maximum Uncertainty Value	Float 32	(FLT_MIN, FLT_MAX)

Table B5 Tracking List Dataset Attributes

Entity Name	Data Type	Domain
Tracking List Item	Bag Tracking List Item	N/A
Tracking List Length	Unsigned Integer32	[0, 2^32-1]

Table B6 Definition of Contents of the BAG Tracking List Item

Entity Name	Data Type	Domain
Row	Unsigned Integer 32	location of the node of the BAG that was modified
Col	Unsigned Integer 32	location of the node of the BAG that was modified
Depth	Float 32	original depth before this change
Uncertainty	Float 32	original uncertainty before this change
track_code	Char	reason code indicating why the modification was made
list_series	Unsigned Integer 16	index number indicating the item in the metadata that describes the modifications

B.2 Digital Signature Scheme

B.2.1 Digital Signature Scheme Implementation

The basic entity of the DSS is the Digital Signature (DS), a multi-byte sequence of digits computed from the contents of the BAG file excluding the certification information and another number, known as the secret key (SK), belonging to the person or entity signing the BAG, known as the Signature Authority (SA). The SK is known only to the SA, and as the name suggests should be kept confidential since knowledge of the SK would allow anyone to certify BAGs as if they were the SA. The DS value can be shown to be probabilistically unique for the contents of the BAG and the SK in the sense that, with vanishingly small probability, no two BAGs would generate the same DS with a particular SK, and no two SKs would generate the same DS with the same BAG.

Corresponding to the SK, there is a public key (PK) that can be distributed freely. There is no way to compute the DS using the PK. However, given a BAG and a DS purported to have been constructed with the SK, it is simple to verify whether the BAG has changed, or if another SK was used to construct the certification.

In addition to the basic DS required for the DSS, the BAG certification block contains a 32-bit integer used to link the certification event with an entry in the metadata's lineage section which describes the reasons for certification. The intent of this is to ensure that the user can provide suitably flexible descriptions of any conditions attached to the certification event, or the intended use of the data so certified. This 'Signature ID' shall be a file-unique sequentially constructed integer so that a certification block can be unambiguously associated with exactly one lineage element.

B.2.2 Structure of the Digital Signature

The BAG DS information shall be maintained in a certification block of length 1024 bytes, appended to the end of the HDF5 data. The ID number shall be a 'magic number' to identify the block, and the version byte shall be used to identify the structure of the remainder of the block

between different versions of the algorithm. The SigID number corresponds to the Signature ID described above, and shall be followed immediately by the DS values which shall be stored sequentially as a length byte followed by the digits of the element. The CRC-32 checksum shall be used to ensure that any accidental or intentional corruption of the certification block will be detectable. The block shall be stored in little endian format, and zero padded to the full size of the block.

B.3 Application Program Interface

B.3.1 Application Program General

All HDF5 access and XML parsing are abstracted from the applications programmer in a BAG Application Programmers Interface.

B.3.2 Structure of the Source Tree

The source code for the BAG access library can be obtained from http://www.opennavsurf.org. The directory structure for the source tree is outlined below. The BAG Application Programming Interface (API) is defined in the api sub-directory, with the primary interface defined in **bag.h**. User-level code should not use any of the deeper interface functions (i.e. those not declared for public consumption in **bag.h**) since they do not present a uniform reporting structure for errors and return codes. Special instructions for compilation and the structure of the library are in a **readme.txt** file in the top level directory. Other **readme.txt** files provide detailed information throughout the remainder of the source tree.

Table B7 Source Tree Structure of the BAG API

Api		BAG API files.
Configdata		Configuration binary files, transformation and other geodetic data.
	ISO19139	Meta-data schemas and definitions.
Docs		Documentation of the BAG file structure.
	Api	`doxygen` documentation of API in HTML form.
Examples		Example source files showing how to exercise the API.
	bagcreate	Create an example BAG given metadata in XML form.
	Bagread	Read a BAG and write formatted ASCII output.
	Excertlib	Sub-library to handle XML DSS certificates.
	Gencert	Generate an XML certificate pair for the DSS.
	sampledata	Small example BAG files for testing.
	Signcert	Sign an XML public key certificate for the DSS.
	Signfile	Sign a BAG file using the DSS.
	verifycert	Verify the signature on a public key DSS certificate.
	Verifyfile	Verify the signature of a BAG using the DSS.
Extlibs		External libraries used by the BAG API.
	beecrypt	General cryptographic library used for the DSS.
	geotrans	General geographic transformations.
	Hasp	Hardware encryption token support library.
	HDF5	Hierarchical Data Format support library, version 5.
	HDF5-linux	Hierarchical Data Format support library, Linux build.
	Lib	Storage for built external libraries.
	Libxml	Simple XML parser library for excertlib support.
	mkspecs	Configuration files for qmake cross-platform support.
	Szip	Scientific code ZIP library (for HDF5).
	Xercesc	Comprehensive XML parser library for BAG metadata.

Zlib	ZIP library (for HDF5).

B.3.3 Basic Data Access

The BAG API supports a standard open/read-write/close process for dealing with BAG files, using **bagFileOpen()** and **bagFileClose()** to open/close existing files, and **bagFileCreate()** to create new files. When creating files, the user is responsible for filling out a bagData structure with the appropriate parameters and data (see bag.h for definitions) before calling **bagFileCreate()**; appropriate XML metadata is required to create a BAG file, bagInitDefinitionsFromFile() can be used, or **bagInitDefinitionsFromBuffer()** can be used if the XML has already been read into memory. A convenience function, **bagInitDefinitionsFromBag()**, for use with pre-existing BAGs will also initialize the BAG definition from the BAG file's Metadata dataset.

The information required to access a BAG file is held in the bagHandle structure that is returned from **bagFileOpen()** or **bagFileCreate()**. This must be preserved throughout any process transaction with a BAG file. User level code cannot use bagHandle directly since it is opaqued in **bag_private.h**. However, access functions such as **bagGetDataPointer()** can be used to obtain any relevant information from the structure, such as a pointer to the data definition arrays, so that user-level code can access file-global definitions like the number of rows or columns in the data grids.

Once the file is open, data can be read either node by node using **bagReadNode()** or **bagReadNodeLL()** for projected and geographic grids, respectively (the type of grid can be found from the metadata), by row using **bagReadRow(),** within a sub-region using **bagReadRegion()** or as a full dataset using **bagReadDataset()**. The last three functions operate in node space, using row/column indices into the array rather than projected or geographic coordinates. Equivalently named calls (e.g., **bagWriteNode()**, **bagWriteNodeLL()**) are available to write data. Note that all data in the mandatory elements are single-precision floating point numbers, but the access calls use pointer-to-void formal parameters in order to opaque this restricted data type for future expansion.

The BAG structure is a uniform grid, defined by the geo-referencing point and a grid resolution in east and north directions. Therefore, no coordinates are required on a per-node basis since they may be computed implicitly from the row/column of the node in question. To assist in this, calls such as **bagReadNodePos()**, **bagReadRowPos()** or **bagReadDatasetPos()** augment the similarly named calls described previously by computing the positions of the rows and columns, which are returned in two linear arrays (one for vertical position of the rows, and one for the horizontal position of the columns) with respect to the grid's coordinate system. Note that this is the only recommended way of computing physical coordinates for nodes, and these positions cannot be computed subsequent to the read/write call.

B.3.4 Metadata Access

XML metadata is treated as a simple binary stream of bytes. The XML stream can be read and written with **bagReadXMLStream()** and **bagWriteXMLStream()** respectively. When complete, the user code should call **bagFreeXMLMeta()** so that any dynamically allocated memory associated with the XML data parser is released.

B.3.5 Tracking List Access

The tracking list component of the BAG file is accessed via direct calls. The number of elements in the list can be read with **bagTrackingListLength()**, and individual nodes in the list may be obtained using **bagReadTrackingListIndex()** using linear indexing into the list. Multiple tracking list items can be read at a time according to a number of different criteria:

bag**ReadTrackingListNode()** returns all of the items associated with a particular grid node, **bagReadTrackingListCode()** returns all items which are tagged with a particular reason code, and **bagReadTrackingListSeries()** returns all items which are tagged with the same metadata series number (i.e., which were all generated with one metadata lineage entry). Similarly named routines to write tracking list entries are also included. If required, the nodes of the tracking list can be sorted according to any of the criteria above using routines such as **bagSortTrackingListByNode()**, **bagSortTrackingListBySeries()**, etc.

B.3.6 Digital Signatures

Key pairs for a DS block are generated with **bagGenerateKeyPair()**, message digests are computed and signed with **bagComputeMessageDigest()** and **bagSignMessageDigest()** respectively, and file signatures can be computed directly using **bagComputeFileSignature()** if the message digest is not required separately.

Certification blocks are read, written and verified by **bagReadCertification()**, **bagWriteCertification()** and **bagVerifyCertification()** respectively. These routines are capable of silently creating a new certificate block at the end of the BAG if one is not present on write.

As convenience for the user who does not want to get into the details of the DSS, the **bagSignFile()** and **bagVerifyFile()** routines are provided to execute all of the stages required to complete signature and verification of a file, respectively. Similarly, the **bagConvertCryptoFormat()** routine can be used to convert signatures, digests or keys into ASCII format so that user-level code can write the data to suitable output files as required. It is the user's responsibility to ensure that secret keys are kept appropriately secret. An example of how to handle this is provided by the **excertlib** project in directory **examples/excertlib/excertlib.c.**

B.3.7 Error Codes and Reporting

All routines from **bag.h** return error codes from the **bagError** enumerated type, which is split into sections corresponding to the components of the library. Human-readable errors messages are available by passing the error code as an argument to **bagGetErrorString()**.

Annex C
GeoTIFF Encoding

(normative)

Note: This encoding needs to be developed. At the moment this section is only a place-holder for a more detailed GeoTIFF encoding specification.

C.1 Encoding Architecture

GeoTIFF is a geographic extension of the popular Tagged Image File Format. It carries an "image" together with some geospatial metadata. The elevation/depth coverage values can be carried as an array as if it were an image. The uncertainity coverage can be carried as a second coincident image. GeoTIFF allows these images to be easily viewed on TIFF display software, so it means that the first level of implementation is readily available. There are also open source GeoTIFF reader/writer software available.

The GeoTIFF encoding only supports the uniform simple quadrilateral grid coverage type form S.102 and S.100; that is a simple raster grid. Only a 2 dimensional grid is supported. Elevation/depth and uncertainty values are handled as data values at the grid cell positions.

The GeoTIFF specification supports some of the discovery metadata within the GeoTIFF file. This is sufficient to name and locate the data. The additional metadata identified in this standard can be carried as an optional associated XML file, or as "private" geotags within GeoTIFF. The problem with private geotags is that they are not reserved and could be in conflict with other users. The problem with an XML file is that it is a separate file that could become separated from the GeoTIFF file. Managing double files is problematic.

A complete specification for a GeoTIFF encoding will be implemented and included in this annex to S.102. In the future it is recommended that discussions be held with the GeoTIFF management group to assign permanent geotags to all of the metadata fields needed to support S.102.

Annex D
Other Encodings

(informative)

Note: This encoding needs to be developed. At the moment this section is only a place-holder for a more detailed GeoTIFF encoding specification.

D.1 Overview of other Bathymetric Surface Product Specification Encodings

Several other encodings for the S.102 Bathymetric Surface product specification are being considered. There needs to be flexibility so that the encoding technique fits the national organization or hydrographic office requirements. Several possible encoding approaches are identified in S.10x Auxiliary Layer specification. Some of the other approaches are: NITIF (ISO 12087-5 BIFF) encoding, and JPEG 2000 encoding.

D.2 XML plus JPEG Encoding

JPEG is a standardized and popular encoding for imagery. The most recent version JPEG 2000 (ISO 15444) support both lossy and lossless data transfer, with significant data compression. Like GeoTIFF it also provides a tag mechanism to imbed metadata. The problem is that JPEG 2000 tools are not yet widespread, so implementation of this encoding approach will be limited. In the future it is expected to become one of the dominant encoding approaches.

There are two methods of encoding using JPEG 2000 for geographic information data. Either the information can be imbedded into JPEG 2000 making for a composite file (which requires special software tools to read), or a "standard" JPEG 2000 file can be associated with an parallel XML file of metadata. There is always the potential problem that the XML file will be separated from the JPEG file, but until the right tools are available, this approach has an advantage of simplicity.

A JPEG tag has already been allocated for GML (Geographic Markup Language) ISO 19136. This means that any GML file can already be imbedded into a JPEG 2000 file, so all of S.102 can be encoded. One only awaits cost effective tools for this approach to be viable.

Annex E
Bibliography

(Informative)

[1] Open Navigation Surface (ONS) project, Center for Coastal and Ocean Mapping University of New Hampshire, http://www.opennavsurf.org

[2] Format Specification Document - Description of Bathymetric Attributed Grid Object (BAG) - Version 1.0.0, Center for Coastal and Ocean Mapping University of New Hampshire,